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ARCHIVES OF SURGERY

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FRACTURES OF THE FEMUR

TREATMENT BY THE RUSSELL METHOD OF TRACTION: REPORT OF TWENTY-ONE CASES *

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My attention was first attracted to the Russell [1] method of treating fractures of the femur in 1927, on reading an article by Ryan [2] of Philadelphia. I herewith report the end-results in twenty-one cases in which this method of treatment was used at the Golden State Hospital, Los Angeles.

I have been impressed by the ease of application of this method and by the comfort it affords the patient. It facilitates the dressing of compound wounds and makes easy daily inspection and measurements. Early massage and other physical therapeutic measures may be given with excellent care of the soft structures and adjacent joints. The method may be used for practically all types of fractures of the femur. The end-results have been excellent, and a minimum of residual disabilities of the joint have occurred as compared with those following other methods.

The object of the Russell method depends on a natural and comfortable position of the limb with relatively small amount of extension to restore equilibrium of the muscle. Russell contended that when the muscles are extended to their normal length the fractured ends of the bones fall more or less into their natural alinement, provided there are no soft tissues interposed between the fragments.

In fractures of the femur, the shortening is due to tonic contraction of the long muscles of the thigh. These muscles have their origin on the pelvic girdle and traverse the entire thigh to be inserted into the tibia and fibula. The aims of traction, therefore, are to stretch these muscles to their normal length, to maintain correct alinement and to permit the bones to resume a more normal position. In order to do this, traction must be applied to the tibia and fibula where the muscles are inserted. Care must be taken that traction is not extended above the knee. Anxiety as regards the ligaments of the knee is needless, for the ligaments are attached to a fragment and cannot then be subjected to stretching. The entire extending force will fall on the muscles.

* Submitted for publication, Nov. 7, 1930.

1. Russell, R. H.: Fracture of the Femur: A Clinical Study, Brit. J. Surg. **11**:491, 1924.

2. Ryan, T. J.: The Use of the Russell Apparatus in the Treatment of Fractures of the Shaft of the Femur, Ann. Surg. **85**:529 (April) 1927.

In addition to this group of long muscles of the thigh, which are active in producing shortening, there are also the adductors, which are inserted into the linea aspera and adductor tubercle of the femur. The function of this group is to adduct and slightly rotate the thigh. The site of the fracture in regard to this group has much to do with alinement. If the line of fracture is high, the lower fragment is displaced medially; if low, the distal fragment is displaced laterally. In the mechanism of most fractures the shearing force is applied ventrally and from the lateral surface, so that naturally the fragments are forced backward and inward. The adductors tend to keep the displaced fragments in that position. This muscular action can be counteracted by varying the degree of adduction or abduction of the thigh, this being controlled by the position of a head to foot bar which is attached overhead to the Balkan frame.

THE APPARATUS AND TECHNIC OF APPLICATION

The material needed is a Balkan frame, four single pulleys 1 inch (2.5 cm.) in diameter, some window weight rope and 1, 2, 3 and 5 pound (0.5, 0.9, 1.4 and 2.3 Kg.) weights. Care should be taken that large pulleys and a small rope are used in order to minimize friction. The frame is attached to the bed, and 6 inch (15.24 cm.) blocks are placed under the foot of the bed. A head to foot bar is attached to the frame parallel to the fractured limb, which is abducted about 10 degrees. This bar carries pulley "*A*" at a point below the knee. A foot piece is attached to the frame which carries pulleys "*B* and *D*." A spreader and another pulley are needed, which are attached to the traction apparatus on the leg.

Some manipulation may be done, but anesthesia is not required. The leg is shaved and closely inspected for wounds. If these are present, they are thoroughly sterilized. Two strips of moleskin adhesive plaster are applied to the lateral and medial surfaces of the leg from the level of the tibial tuberosities distally to a spreader which is placed 2 inches (5 cm.) beyond the plantar surface of the foot. This spreader carries pulley "*C*." The spreader should be broad enough to prevent pressure on the malleoli by the adhesive traction straps. Thin cotton pads placed over the malleoli give added protection. A bandage is wrapped loosely over the adhesive and around the leg from the ankle to the knee.

The traction pulleys are placed in the following manner: Pulley "*A*" is suspended from the lower surface of the overhead bar at a point vertically above the junction of the tuberosities and shaft of the tibia. Pulleys "*B*" and "*D*" are attached separately to the traction bar beyond the foot of the bed. Pulley "*C*" is attached to the center of the distal surface of the spreader.

A broad canvas sling which has been padded with soft felt for comfort is passed beneath the knee. The canvas is firmly attached to a spreader or block. From this spreader the cord is passed as follows: through pulley "*A*"; through pulley "*B*" on the traction bar beyond the bed; through pulley "*C*" on the spreader; through pulley "*D*" on the traction bar beyond the foot of the bed where the weight is attached. The surgeon stands at the foot of the bed and tightens the ropes and applies the weights. A soft pillow is placed under the thigh and so adjusted as to prevent posterior angulation at the site of fracture. Another pillow is placed under the leg and achilles tendon so as to prevent the heel from touching the bed. The limb comes to rest in a position of not more than 10 degrees

of abduction and one-fourth normal flexion. In most of the cases reported here it was found that a straight pull gave better reduction than a pull through abduction. The position of the leg is, roughly, one parallel with the bed, the heel almost but not quite touching the bed.

Usually no difficulty is encountered with eversion, the upward traction on the knee, which is in a position of flexion, tending to prevent it. If too much eversion does occur, it can easily be corrected by attaching a small weight to the spreader at the foot.

Weights Required for Reduction and its Maintenance.—The weight first attached is 8 pounds (3.6 Kg.) for adults. Russell stated that for infants and young children he uses from ½ to 4 pounds (0.25 to 1.8 Kg.) and for children up to 14 years of age 6 pounds (2.7 Kg.). At the end of three or four days roentgenograms are taken to check the progress of reduction. If the overriding persists, an extra 2 or 3 pounds are added. The weight required for maintaining

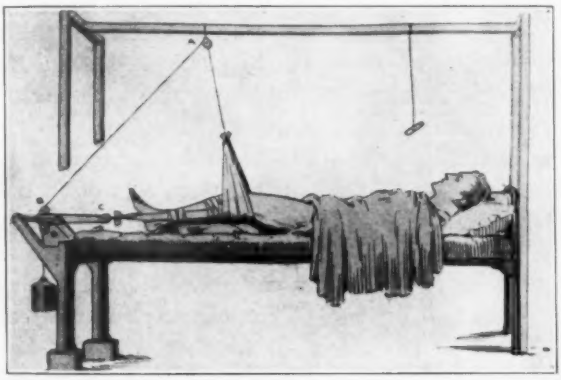

Fig. 1.—Russell traction apparatus. (From Brit. J. Surg. **11**:492, 1924.)

correct reduction is determined by roentgenograms and frequent measurements. After the third week, 5 or 6 pounds of weight has been found to be sufficient to maintain reduction until clinical union has occurred. The mechanics of the traction method are such that the vertical and horizontal pull on the knee is practically twice the horizontal pull on the leg, a slight loss being due to friction of the rope and pulleys.

AFTER-CARE OF THE PATIENT

The apparatus is inspected daily, care being taken to see that the pillows are in place to prevent posterior bowing at the site of fracture and pressure of the heel on the bed.

When there is clinical evidence of firm union, traction is removed, and the patient is kept in bed for one week. During this time free motion is allowed, and he may sit on the edge of the bed with his legs hanging over. If union is not firm, pain is experienced at the site of the fracture, and angulation occurs. If roentgenograms demonstrate angulation, the traction is replaced.

If angulation has not taken place during the week after discontinuance of the traction, the patient is allowed to use crutches, usually without any accessory support. In certain cases in which the callus appears somewhat sparse and shows a lack of normal deposition of calcium, the patient has been fitted with a walking caliper splint which is worn until union is solid. Physical therapy is given in the form of electrical stimulation, both galvanism and faradism, together with diathermy. Massage and early motion at the joints are begun. As soon as the callus is sufficiently solid, weight-bearing on the limb is encouraged. First one crutch and then the other is replaced by a cane. Disability terminates when the patient can walk without the use of a cane and is able to resume the usual occupation with maximum function of the ankle, knee and hip joints.

Russell stated that whether the fracture is in the upper, middle or lower third of the femur, the treatment is exactly the same. The position of the limb and mode of extension is equally appropriate in all three conditions. The visible displacement, which is caused by muscular action, is only a transient phenomenon and will disappear as soon as the limb is placed in a comfortable position. He entirely disregards the proximal fragment and places the limb in a position that is natural and comfortable, with the assurance that the position natural and comfortable for the entire limb will be equally so for the proximal fragment in common with the rest, and that such position will be that which the proximal fragment will assume. The position is roughly one of about 4 inches (10.16 cm.) abduction at the hip with one-fourth normal flexion at the knee.

To recapitulate, in fractures of the femur, given a method of stretching out the muscles of the thigh to their normal length by an appliance that is perfectly comfortable, nothing will remain to be done except to overcome the force of gravity at the site of the fracture. The simplicity of this principle makes it the more practicable, and the method has proved to be so in practice.

ANALYSIS OF CASES

Twenty-one patients with fractures of the femur have been treated by the Russell method at the Golden State Hospital. The anatomic distribution of the fractures is shown in table 1.

In two of the cases, the fractures were compound. Thirteen cases showed certain degrees of comminution, four of which were severely comminuted. In four cases, the line of fracture extended into the lesser trochanter. The lesser trochanter was completely separated from its attachment in three cases. One of the patients had sustained a double fracture, the lines of fracture being through the proximal and distal thirds, respectively. In case 3, both femurs were fractured.

Most of the patients suffered from varying degrees of shock, three to a marked degree. Other injuries were sustained in the majority of the cases, the nature of which are given in table 2.

The after-care of the patients presented certain medical complications as shown in table 3.

TABLE 1.—*Anatomic Distribution of Fractures*

Location		Number
Intertrochanteric		3
Pertrochanteric		2
Shaft	Proximal one-third	7
	Middle one-third	7
	Distal one-third	4
Total		23

TABLE 2.—*Other Injuries Sustained By Patients*

Injury	Number
Severe contusions of the thigh	4
Lacerations of the scalp	3
Cerebral concussion	3
Fracture of the humerus	2
Fracture of the ribs	2
Fracture of the radius-ulna	2
Rupture of the spleen	1
Compound fracture of the tibia-fibula	1
Acute sprain of the knee	1
Fracture of the radial styloid	1
Lacerations of the forearm	1
Paralysis of the peroneal nerve	1

TABLE 3.—*Complications Presented*

Complication	Number
Hypertrophic arthritis	5
Arteriosclerosis with hypertension	3
Acute bronchitis	2
Cystitis	2
Myocarditis with decompensation	1
Acute retention with prostatic hypertrophy	1
Syphilis	1

In none of these cases did decubital ulcers develop. The patient in case 8 was about ready to resume work when he slipped and fell down a flight of stairs, refracturing the femur. The line of fracture was through the recently hardened callus. Four of these patients had been treated at other hospitals prior to their examination at the Golden State Hospital.

1. The patient in case 3 sustained a fracture of the shafts of both femora on Aug. 3, 1927. He was treated by manual reduction and the

application of a plaster body cast. He was transferred to the Golden State Hospital thirteen days after the injury, at which time measurements showed 2 inches of shortening.

2. The patient in case 7 sustained a fracture of the shaft of the right femur on July 11, 1927. He was treated by traction on a modified Thomas splint. He was transferred to the Golden State Hospital fifty-one days after the injury, at which time measurements showed 1 inch of shortening.

3. The patient in case 16 sustained a fracture of his left femur in the subtrochanteric region on March 12, 1929. Traction was unsuccessful, so an open reduction was performed on March 31, and the fragments held in position by a Lane plate. The cast was removed at the end of four weeks, and the patient was allowed to use crutches. He was transferred to the Golden State Hospital on May 14, two months after the injury. Examination showed considerable angulation and 1 inch of shortening.

4. The patient in case 18 sustained a fracture of the right femur in the intertrochanteric region on Dec. 5, 1929. The fracture was immobilized by a plaster body cast. He was transferred to the Golden State Hospital after ten days, when measurements showed 1 inch of shortening.

With the exception of these four cases, the traction was applied the same day that the accident occurred.

Nineteen of the patients treated were males; two were females. The average age was 42, the youngest patient being 17 and the oldest 74.

One patient, a woman, aged 74, died. She was in a state of profound shock and failed to respond to treatment.

All the patients were treated at the Golden State Hospital, Los Angeles, under the direction of Dr. Sam Herzikoff, chief surgeon, except the patient in case 21 who was one of Dr. Herzikoff's private patients and was treated at home, the Balkan frame and other apparatus having been supplied from the hospital.

The patient in case 22 is still under treatment. The case is introduced to show the rapidity and ease with which impaction may be reduced and an almost perfect alinement obtained through the use of 8 pounds of weight, according to the Russell method.

The accompanying illustrations are sepia-wash drawings of actual roentgenogram tracings, and were made by me.

A résumé of the histories of the cases follows:

CASE 1.—J. M., a youth, aged 17, was injured on April 18, 1929, when the motorcycle on which he was riding collided with an automobile. He was unconscious for forty-five minutes. Examination showed the following injuries: (1)

fracture of the left femur, (2) severe laceration of the scalp with cerebral concussion, (3) contusions of the upper part of the abdomen and (4) generalized contusions of the body and abrasions of the skin.

The patient was in marked state of shock. Roentgenograms of the left femur showed an oblique spiral fracture at the junction of the middle and upper thirds with overriding of about 1½ inches (3.77 cm.). The upper fragment was displaced anteriorly and inward. Russell traction was applied with 8 pounds of weight. On April 20, the patient complained of severe pain in the left upper quadrant of the abdomen and in the left shoulder. An exploratory laparotomy

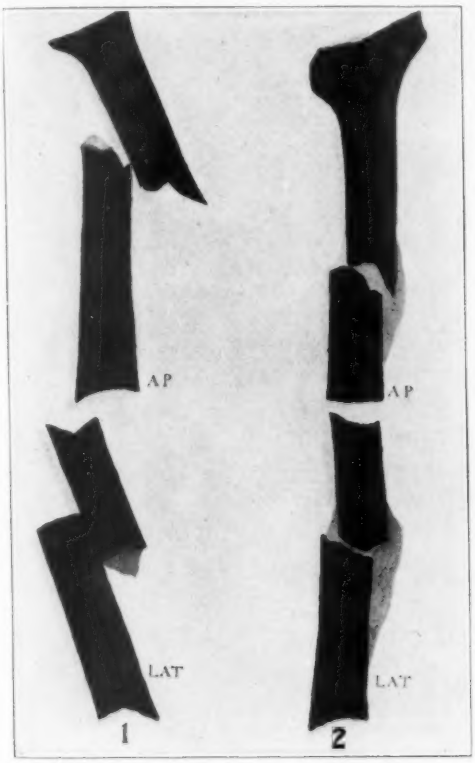

Fig. 2 (case 1).—Roentgenograms taken on: *1*, April 18, 1929; *2*, June 24, 1929.

was done, and a ruptured spleen removed. Recovery was uneventful. Following this operation, the patient's left leg was replaced in Russell traction. Roentgenograms taken on June 24, nine and one-half weeks after injury, showed abundant callus, particularly along the external surface. Alinement was good with slight angulation at the site of the fracture. There was slight inward and backward displacement of the distal fragment, but no shortening. Clinical examination showed firm union. Traction was removed. Motion in the ankle joint was normal, and motion in the knee joint showed complete extension with flexion of about 75 degrees. Measurements showed the left limb to be ¼ inch (0.63 cm.) shorter than the right. The patient was given intensive physical therapy and allowed to use crutches. No protective brace was applied. The patient returned

to work on Jan. 23, 1930, nine months after injury. Examination showed that he walked without a limp. The limbs were normal externally except for slight atrophy of the muscle of the left thigh. The motion of the hip, ankle and knee joints was within normal range.

CASE 2.—J. P., a man, aged 54, was injured on April 4, 1929, when a heavy steel girder fell from a dolly on which it was being carried and struck the patient's right thigh. Examination revealed: (1) fracture of the right femur and (2) fracture of the right radial styloid. The roentgenograms showed an

Fig. 3 (case 2).—Roentgenograms taken on: *1*, April 4, 1929; *2*, June 4, 1929.

oblique fracture of the midportion of the femoral shaft with overriding of about 1½ inches. The distal fragment was displaced posteriorly and slightly inward. Russell traction was applied with 8 pounds of weight. Roentgenograms taken on April 11 showed that the overriding had not been completely corrected, so 3 additional pounds of weight was added. Roentgenograms taken on May 11 showed good alinement with end to end apposition. The additional weight was removed. Examination on June 4, nine weeks after injury, showed firm clinical union. Traction was removed. The roentgenograms showed the presence of abundant callus. The alinement was good, and the overriding was corrected. The motion of the ankle was normal, while motion of the knee showed normal extension with flexion of about 25 per cent. A walking caliper splint was applied,

and the patient was allowed to use crutches. He was given intensive physical therapy. During convalescence, he complained of moderate swelling of the entire extremity. The crutches were gradually discarded. Early in September, 1929, five months after the accident, the patient began to remove the brace and to bear weight on the injured member. He returned to light work on Nov. 14, 1929, seven and one-half months following the accident. Examination showed a slight weakness of the right lower extremity. The patient walked without a limp, and measurements showed the length of the lower extremities to be equal. Motion of the ankle and hip was normal. Flexion of the right knee was impaired 10 per cent.

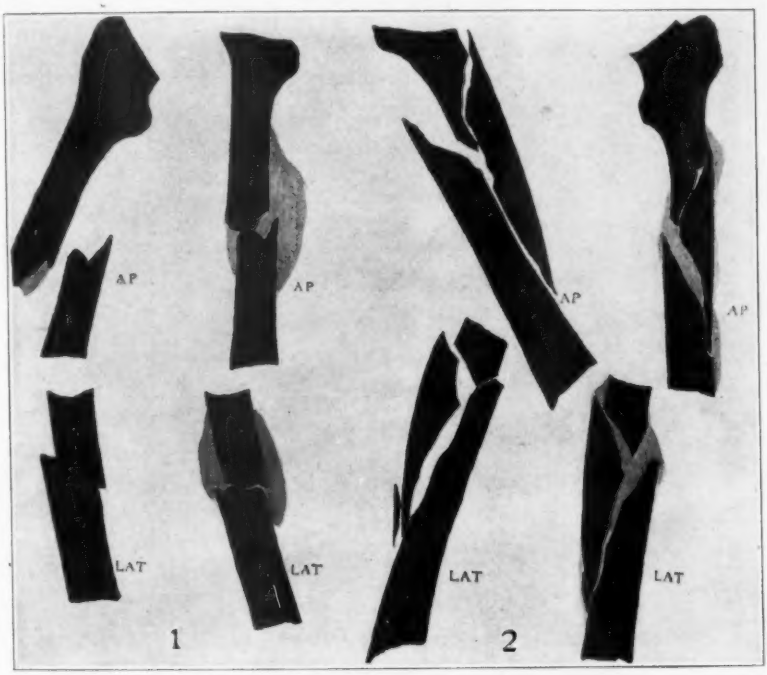

Fig. 4 (case 3).—Roentgenograms of the left femur taken on: *1,* Aug. 3 and Sept. 28, 1927; *2,* roentgenograms of the right femur.

Case 3.—J. B., a youth, aged 19, was injured on Aug. 3, 1927, when an automobile in which he was ridding skidded from the highway over an embankment. The patient was rendered unconscious. He was taken to a nearby hospital, where he was placed in a body cast; on August 16, he was transferred to the Golden State Hospital. Examination showed the following injuries: (1) fractures of the shafts of both femora, (2) fracture of the neck of the right humerus and (3) fracture of the right first and left second ribs. The left femur showed a long comminuted spiral fracture involving about 9 inches (22.9 cm.) of the shaft, the distal fragment being displaced inward and posteriorly the width of the shaft. A large triangular fragment 8 inches (20.3 cm.) long was detached from the upper and external portion of the femur, the upper level of this fragment being opposite

the base of the lesser trochanter, while the lower level was at the junction of the middle and lower thirds of the shaft. The fragments were overriding about 2 inches and were badly malalined.

The right femur showed an irregular transverse fracture of the shaft through the junction of the upper and middle thirds. The ends were wholly displaced, and the fragments were overriding about 2 inches. The distal fragment was displaced inward and posteriorly.

Russell traction was applied with 8 pounds of weight to each extremity. Examination on September 28, eight weeks after injury, showed firm clinical

Fig. 5 (case 4).—Roentgenograms taken on: *1*, June 21, 1929; *2*, Sept. 9, 1929.

union. The roentgenograms showed good alinement with correction of the overriding. There was a marked formation of callus. Clinically, the legs were straight, and measurements showed them to be of practically the same length. Motion of both ankles was normal, while motion of both knees showed complete extension with flexion of about 60 per cent. The patient was able to raise both legs from the bed. He was allowed to use crutches. He was discharged from the hospital on October 14. On October 21, he discarded his crutches for a cane, and on November 22, he walked without support, complaining only of tiring easily. He returned to work on Feb. 1, 1928, six months after the accident. The muscle tone was good. He walked without a limp. The measurements showed

the legs to be of the same length, though the patient claimed he was 1 inch shorter than before the accident. No pain or tenderness was felt at the site of the fractures. Motion of the ankle, knee and hip was normal.

CASE 4.—F. G., a youth, aged 18, was injured on June 21, 1929, when he cranked his truck while it was in gear. The truck lurched ahead, crushing his right thigh against a building. The roentgenograms showed a transverse fracture of the right femur at the junction of the middle and lower thirds. There was backward and inward displacement of the distal fragment with complete separation of the fragments. There was overriding of 1 inch. A free fragment was seen lying on the upper surface of the lower fragment. Russell traction was applied with 8 pounds of weight. Roentgenograms taken on June 25 showed that the overriding was not completely corrected. Three additional pounds of weight was added. On September 9, eleven weeks after injury, examination showed firm clinical union. Traction was removed. The roentgenograms showed consider-

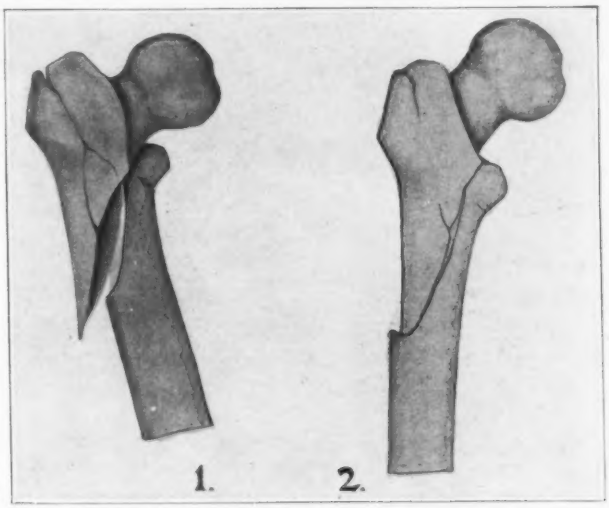

Fig. 6 (case 5).—Roentgenograms taken on: *1,* May 17, 1927; *2,* Aug. 24, 1927.

able callus. There was slight backward displacement of the distal fragment about one-third the width of the shaft and slight internal displacement of the upper fragment. Apposition was good. The patient was allowed to remain in bed for ten days, when roentgenograms showed no increase in deformity. He was then allowed to use crutches. No protective brace was applied. Motion of the ankle was normal, while that of the knee showed complete extension with flexion of about 35 per cent. The patient was referred to the physical therapy department. He was discharged from the hospital on September 30. On December 1, he began to bear weight, and on Feb. 21, 1930, eight months after the injury, he returned to light work. His only complaint was slight weakness of the right lower extremity with soreness at the site of the fracture at the end of the day. Examination on March 21 showed that the patient walked without a limp. There was no muscular atrophy. Measurements of the limbs showed the right one to be about ½ inch shorter than the left. The motion of the ankle, knee and hip was normal.

CASE 5.—J. D., a man, aged 31, was injured on May 17, 1927, when a plank on which he was walking broke, and he fell 18 feet to the ground. The plank followed him and struck his right thigh. Examination showed: (1) fracture of the right femur and (2) clinical signs of syphilis (saddle nose, perforated septum, penile scars). The Wassermann reaction of the blood was 3 plus. The roentgenograms showed a long oblique fracture of the upper one third of the shaft of the right femur extending to the level of the lesser trochanter. The distal fragment was displaced inward and upward so that the fragments were overriding about 1 inch. There was a secondary line of fracture through the greater trochanter and another at

Fig. 7 (case 6).—Roentgenograms taken on: *1*, Nov. 26, 1928; *2*, Jan. 22, 1929.

the base of the lesser trochanter. Russell traction was applied with 8 pounds of weight, and antisyphilitic treatment was instituted. On July 6, seven weeks after the injury, roentgenograms showed excellent position and alinement with apparent union, so that traction was removed. The fragments, however, did not remain in position so that traction had to be reapplied. On August 24, fourteen weeks after injury, traction was removed. The roentgenograms showed excellent alinement and position. Examination showed firm clinical union. The patient was fitted with a walking caliper splint and allowed to use crutches. On November 7, the caliper splint was removed, and the patient used only a cane. He complained of pain in the right groin. On Feb. 4, 1928, nine months after fracture, he returned to work. He walked without a limp. There was slight atrophy of the muscle of

the right thigh. The measurements showed the right limb to be ¼ inch shorter than the left. Motion of the hip, ankle and knee was normal.

CASE 6.—R. D., a youth, aged 19, was injured on Nov. 26, 1928, when a 20 pound block of ice fell from the top of a refrigerating car and struck his right thigh. The roentgenograms showed a comminuted fracture of the shaft of the right femur at about its middle third. There was complete separation of the ends of the fracture with overriding of about 2 inches. There was marked inward angulation with the proximal fragment pushed inward and overriding the distal fragment anteriorly. The upper 2 inches of the lower fragment was badly com-

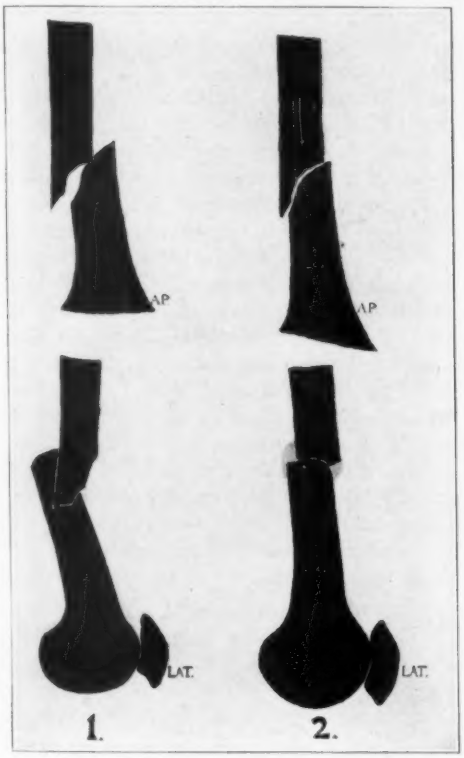

Fig. 8 (case 7).—Roentgenograms taken on: *1*, July 11, 1927; *2*, Oct. 19, 1927.

minuted. Russell traction was applied with 8 pounds of weight. Roentgenograms on December 15 showed that the overriding had been practically corrected. There was still, however, considerable inward angulation, so that 3 pounds of side traction was placed at the site of the fracture. Roentgenograms taken on Jan. 22, 1929, eight weeks after fracture, showed considerable callus. Alinement was satisfactory, though slight inward and backward angulation still persisted. Clinically firm union was present, so traction was removed, and the patient was allowed to use crutches. No supporting splint was applied. Motion of the ankle was normal. The knee could be flexed to the right angle. On February 21, a cane was substituted for crutches; on March 3, the cane was discarded. The patient returned to work on May 13, five and one-half months after fracture. Examina-

tion showed slight fulness at the site of the fracture due to bone prominence immediately beneath the soft tissues in front of the middle one third of the thigh. The patient walked with a very slight limp. Measurements showed the right thigh to be shorter than the left by ½ inch. Motion in the hip, knee and ankle was normal.

CASE 7.—J. N., a man, aged 25, was injured on July 11, 1927, when a heavy water tank which he was helping to unload slipped from the wagon and fell across his right thigh. He was taken to a nearby hospital where the limb was placed in a modified Thomas splint; on August 31, he was transferred to the Golden State Hospital. Roentgenograms taken on September 2, showed an oblique fracture of the shaft of the right femur about 5½ inches (14 cm.) above the knee joint. The distal fragment was displaced the width of the proximal fragment and angulated posteriorly, overriding the proximal fragment about 1 inch. There was no sign of callus. Russell traction was applied with 8 pounds of weight. Roentgenograms taken on September 13 showed greatly improved alinement but considerable external bowing. Three pounds of lateral pull was attached. On October 19, thirteen weeks after fracture, roentgenograms showed the alinement in the antero-posterior plane to be very good. The distal fragment was displaced backward about one-half the width of the shaft but without overriding. Clinical union was firm, so traction was removed and a walking caliper splint applied. Flexion of the knee was present through about 25 degrees. The patient was referred to the physical therapy department for intensive treatments. He made slow progress, so that it was necessary on December 15 and Jan. 2, 1928, to manipulate the knee under gas anesthesia. The patient was discharged from the hospital on January 13. He was wearing a caliper splint at all times. There was present moderate atrophy of the entire right lower extremity. Flexion of the knee was present to 75 degrees. On March 3, the caliper splint was discarded. On May 15, the patient returned to work, ten months after injury. Examination showed slight atrophy of muscles of the right thigh. The patient walked without a limp, though measurements showed the right limb to be ½ inch shorter than the left. Motion in the ankle and hip was normal. Flexion of the knee was impaired 15 per cent.

CASE 8.—S. Q., a man, aged 22, was injured on June 1, 1927. He was standing on the edge of a ditch when the walls caved in, so that he fell into the ditch and into the chains of a ditch digger. The following injuries were sustained: (1) fracture of the left femur, (2) fracture of the right tibia and fibula and (3) extensive lacerations of the right forearm. Roentgenograms of the left femur showed a short oblique fracture of the shaft at about the junction of the middle and upper thirds. There was overriding of about 1 inch. A triangular fragment about 2½ inches (6.27 cm.) was detached from the posterior surface of the distal fragment. Russell traction was applied with 8 pounds of weight. Clinical examination on August 3, nine weeks after the fracture, showed firm union, so traction was removed. The roentgenograms showed considerable callus. The ends were in apposition for more than three-fourths of their surface, and alinement was good. On November 25, the patient was bearing full weight on the injured limb. There was complete restoration of function, and he was about ready to resume work when he slipped and fell downstairs, refracturing his left femur. The roentgenograms showed the fracture to be through the newly formed bone. There was marked outward angulation, the distal fragment being displaced inward and posteriorly. There was overriding of about 2 inches. The leg was placed in traction with 8 pounds of weight. Examination on Feb. 1, 1928, nine weeks after fracture, showed firm clinical union. The roentgenograms showed reunion with slight posterior bowing.

The ends were in apposition. There was 35 per cent flexion of the knee. Traction was removed, and the patient was kept in bed. He was allowed to use crutches on March 21, and was referred to the physical therapy department. He was discharged from the hospital on May 15. On July 17, he returned to work, eight months after the second fracture and thirteen months following the original fracture. The limbs were equal in length, and the patient walked without a limp. The muscles of the thigh were not atrophic. Motion of the hip and ankle joints was normal. Flexion of the knee was impaired about 10 per cent.

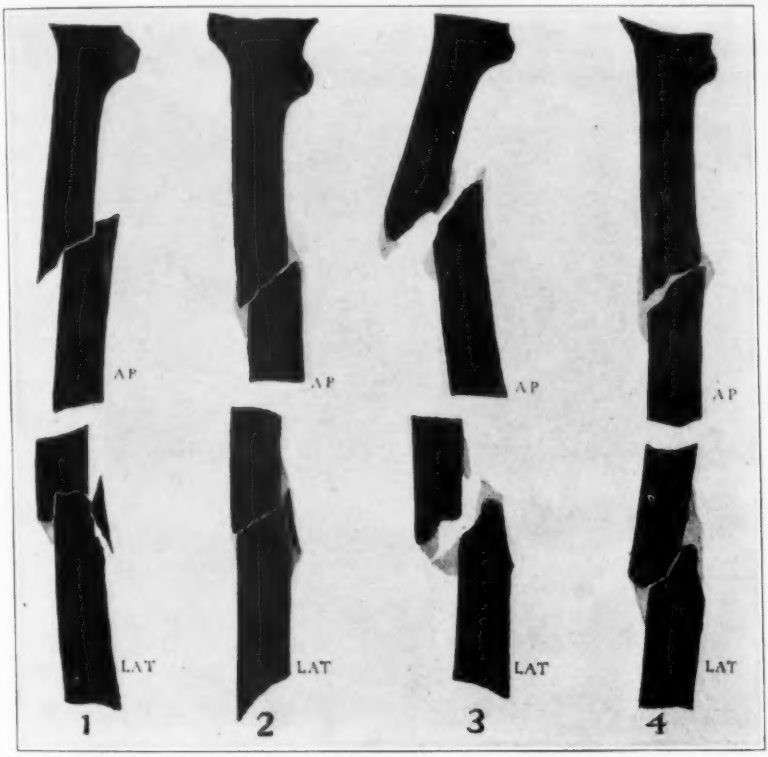

Fig. 9 (case 8).—Roentgenograms taken on: *1*, June 1, 1927; *2*, Aug. 3, 1927; *3*, refracture, Nov. 25, 1927; *4*, Feb. 1, 1928.

CASE 9.—G. J., a man, aged 58, was injured on Nov. 13, 1928, when he was struck by an automobile while crossing a street. He was in a state of considerable shock. The roentgenograms showed a long comminuted oblique fracture of the upper third of the shaft of the left femur. The upper fragment was split longitudinally in half, the posterior portion being displaced posteriorly and inward. The lesser trochanter was comminuted and detached. There was overriding of about 1½ inches. The leg was placed in Russell traction with 8 pounds of weight. Convalescence was complicated by myocarditis with partial decompensation and acute retention from a hypertrophied prostatic median lobe. On Jan. 26, 1929, ten weeks after fracture, traction was removed but considerable bending

occurred at the site of the fracture, so traction was reapplied. On April 26, twenty-three weeks after fracture, there was a firm clinical union with good callous formation, so traction was again removed and a caliper splint applied. Roentgenograms taken on May 4 showed no recurrence of deformity, so the patient was allowed to use crutches. Flexion of the knee was 25 per cent normal. On September 26, the caliper splint was discarded. Examination on Jan. 15, 1930, showed perfect clinical union. The patient walked with a slight limp, and measurement of the limbs showed shortening of ¾ inch (1.9 cm.). Motion of the ankle was normal. Extension of the knee was normal; flexion was impaired 10 per cent. Flexion of the left hip was 114/130, and extension was normal. Abduction was limited 10 per cent. Adduction and external rotation were normal, while internal rotation was limited 15 per cent. The patient was able to work, but was prevented due to an attack of acute cardiac decompensation.

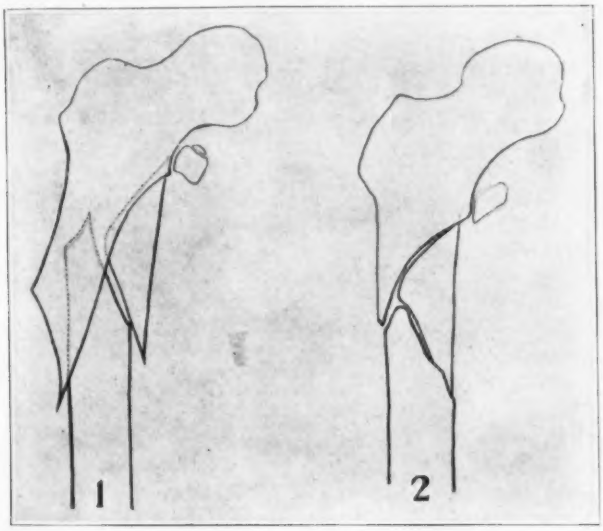

Fig. 10 (case 9).—Roentgenograms taken on: *1*, Nov. 13, 1928; *2*, Jan. 26, 1929.

CASE 10.—J. E., a man, aged 63, was injured on Nov. 26, 1929, when he was caught in an elevator shaft and dragged to the basement. He sustained a compound fracture of the left femur and a compound fracture of the left humerus. Physical examination showed chronic bronchitis and hypertension with arteriosclerosis. The roentgenograms showed a comminuted fracture of the midportion of shaft of the left femur with overriding of 2 inches. There was a large fragment completely detached from the outer and posterior portion of the shaft. The leg was placed in Russell traction with 8 pounds of weight. Roentgenograms taken on December 26, showed inward angulation which was corrected by outward traction. Examination on Feb. 26, 1930, twelve weeks after injury, showed firm clinical union, so traction was removed and a walking caliper splint applied. The knee showed complete extension with flexion of 50 degrees. Motion of the ankle was normal. The patient was given intensive physical therapy. The caliper splint was discarded on April 28. On May 28, the patient walked with only a cane. He returned to work on August 1, eight months after injury. Examination showed

that he walked without a limp, the limbs measuring the same. There was some muscular atrophy. Motion of the ankle, knee and hip was normal.

CASE 11.—S. P., a man, aged 48, was injured on Aug. 4, 1929, when he slipped on a wet floor, fell and fractured his right thigh. The roentgenograms showed an irregular transverse fracture of the femoral shaft about 6 inches above the knee with complete displacement of the fragments and overriding of 1½ inches. The distal fragment was displaced anteriorly and inward. Russell traction was applied with 8 pounds of weight. Callus was very slow in forming. Examination on December 26 showed evidence of union so that a caliper splint was applied. Five

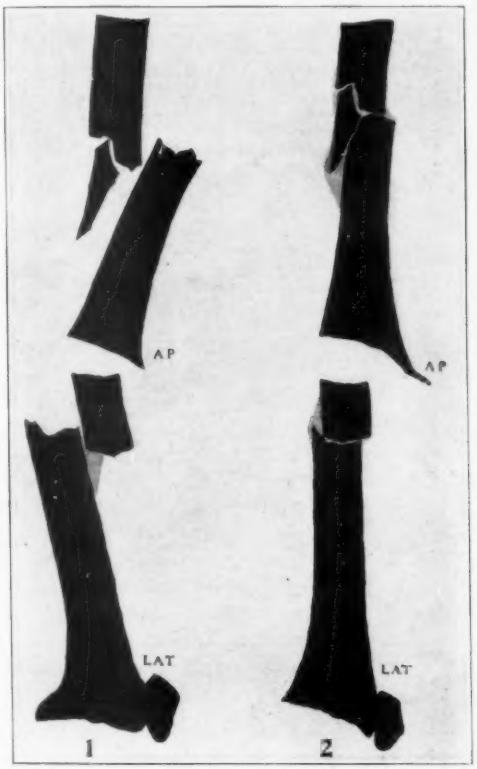

Fig. 11 (case 10).—Roentgenograms taken on: *1*, Nov. 26, 1929; *2*, Feb. 26, 1930.

days later the patient began to complain of pain at the site of the fracture, and there was evidence of bowing. Traction was reapplied. Examination on Feb. 18, 1930, twenty-eight weeks after the accident, gave evidence of firm union. The roentgenograms showed good alinement and position with abundant callus. The walking caliper splint was reapplied. Motion of the ankle was normal. Extension of the knee lacked 10 degrees of being normal; flexion was possible through 25 degrees. There was marked muscular atrophy of the right thigh and leg. The patient was given intensive physical therapy. On July 9, the caliper splint was discarded. On August 1, the patient walked with only the aid of a cane. There was no limp, no shortening and only moderate muscular atrophy. Motion of the

Fig. 12 (case 11).—Roentgenograms taken on: *1*, Aug. 4, 1929; *2*, Feb. 18, 1930.

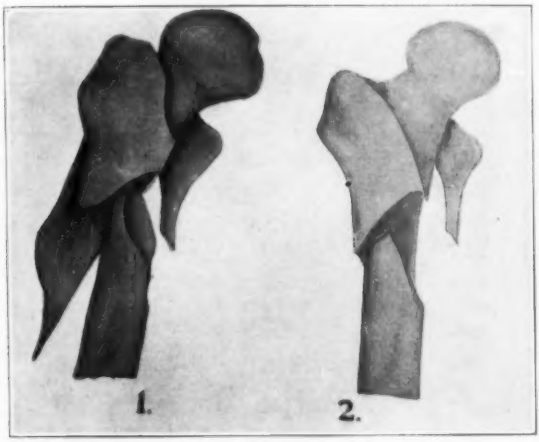

Fig. 13 (case 12).—Roentgenograms taken on: *1*, Dec. 31, 1927; *2*, Jan. 14, 1928.

ankle and hip was normal. The knee showed complete extension with 15 degrees impairment of flexion. The period of further disability was estimated at two months, making the total period of disability fourteen months.

CASE 12.—J. R., a man, aged 36, was injured on Dec. 31, 1927, when he fell from the top of an ice truck 20 feet to the pavement. He suffered considerable shock. The roentgenograms showed a severely comminuted fracture of the left femoral shaft in the subtrochanteric region. The lesser trochanter was completely separated from the shaft and displaced upward and posteriorly. The fragments were widely separated. External measurements showed 2 inches of shortening. Russell traction was applied with 8 pounds of weight. Roentgenograms taken on Jan. 14, 1928, showed that shortening was only partially overcome and that fragments were still separated, so 3 additional pounds of weight was added. Roentgenograms taken on February 4 showed good alinement and apposition, so the extra weight was removed. On March 23, twelve weeks after injury, examination showed firm union. Traction was removed, and the patient was fitted with a walking caliper splint and allowed to use crutches. On June 28, the caliper splint was discarded. The patient returned to light work on August 16, seven and one-half months after fracture. He complained of occasional pain in the left hip, and walked with a slight limp. Measurements showed about ¾ inch of shortening. Extension of the knee was complete with 10 degrees impaired flexion. Flexion of the hip was impaired 20 per cent. Adduction and external rotation were slightly impaired. Other motions were normal.

CASE 13.—J. W., a man, aged 33, was injured on June 9, 1929, when a large rock which was thrown into the air from an explosion fell on his left thigh, causing a compound fracture of the left femur. The roentgenograms showed a transverse fracture of the shaft at the junction of the middle and lower thirds with overriding of about 3 inches (7.6 cm.). The distal fragment was displaced posteriorly. Russell traction was applied with 8 pounds of weight. The wound in the thigh healed without infection. On June 26, the fracture was not reduced, the distal fragment remaining displaced posteriorly. On June 27, skeletal traction was applied to a Steinman nail which was passed through the upper part of the tibial shaft. Roentgenograms taken on July 28 showed good alinement and position anteroposteriorly but complete displacement posteriorly. There was no sign of callus formation. An open reduction was performed, and a band of muscle the thickness of one's palm was found interposed between the fragments. An intramedullary peg was inserted, and a body plaster cast applied.

CASE 14.—J. B., a man, aged 24, was injured on June 24, 1929, when a heavy piece of lumber was "kicked back" by a rip saw and struck his right thigh. He suffered moderate shock. The roentgenograms showed a comminuted fracture of the shaft of the right femur at the junction of the middle and lower thirds. There was overriding of about 2 inches. The leg was manipulated without anesthesia and placed in Russell traction with 8 pounds of weight. Roentgenograms taken on July 24, in the anteroposterior plane, showed good position and alinement. Lateral views showed continued posterior displacement of the distal fragment with about ¾ inch of overriding. There was a fair amount of callous formation. Callus continued to form, but no union occurred. The case was considered one of delayed union. The patient was given calcium and viosterol. On December 11, as there was no union, an open operation was performed. A large band of muscle fibers was found between the ends of the bone. This band was liberated, and an intramedullary inlay placed. Recovery was uneventful.

Case 15.—J. C., a man, aged 39, was injured on June 4, 1928, when a derrick on which he was working collapsed and he fell 20 feet to the ground. Examination showed a fracture of the left femur and fracture of the left ninth and tenth ribs. The roentgenograms showed a markedly comminuted pertrochanteric fracture, the main line of fracture running obliquely from a mesial point just above the lesser trochanter to the outer side of the shaft below the greater trochanter. The lesser trochanter was completely detached and comminuted. There was a secondary line of fracture running longitudinally through the greater trochanter. There was a marked coxa vara deformity. Measurements showed the leg to be shortened 2½ inches. Russell traction was applied with 8 pounds of weight. Examination on August 24, eleven and one-half weeks after injury, showed firm clinical union, so traction was removed. The roentgenograms showed good alinement and position with bony union. A caliper splint was applied, and the patient was given physical therapy. On Jan. 9, 1929, he discarded the caliper splint. On March 1, nine months after injury, he returned to work. He walked with a slight limp. Measurements showed ½ inch of shortening. Motion in the left hip was

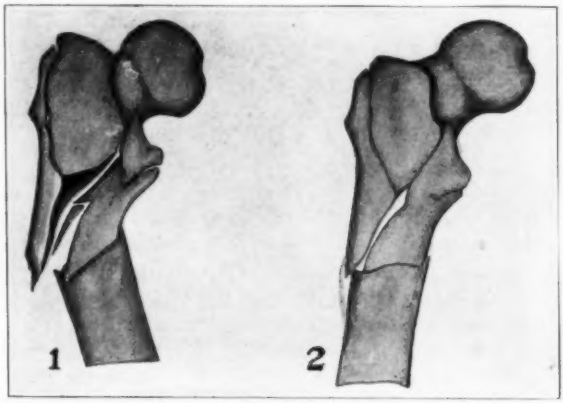

Fig. 14 (case 15).—Roentgenograms taken on: *1*, June 4, 1928; *2*, Aug. 24, 1928.

normal, except for 50 per cent impairment of internal rotation. The left knee showed complete extension with 10 per cent impaired flexion. Motion of the ankle was normal.

Case 16.—K. K., a man, aged 34, was injured on March 12, 1929, when some 125 pound (56.7 Kg.) sacks of potatoes fell on his left thigh. He sustained a fracture of the left femur. He was taken to another hospital where he was treated by traction for ten days without success. Open operation was done on March 21, a Lane plate being used. A cast was applied; it was removed on April 25, and the patient was allowed to use crutches. Increasing deformity resulted. He was transferred to the Golden State Hospital on May 14. The roentgenograms showed an old transverse subtrochanteric fracture of the left femur. The fragments were in end-to-end position, but there was marked outward and backward bowing. The Lane plate was present, but the screws were pulled loose. There was a fair amount of callus. Measurements showed 1 inch of shortening. Traction was applied with 8 pounds of weight. Examination on June 24 showed firm union, so traction was removed. Roentgenograms showed good alinement and position. Measurements of both legs showed equal length. Motion of the ankle was normal. The knee

showed full extension, with 20 per cent impaired flexion. The patient was referred to the physical therapy department. He began weight-bearing on August 8. He returned to work on Jan. 1, 1930, nine and one-half months after the accident. There was slight atrophy of the muscles. Measurements of the legs showed equal length. Motion of the hip, knee and ankle was normal.

CASE 17.—G. M., a man, aged 57, was injured on Aug. 27, 1928, when he fell from a ladder 7 feet to a concrete floor. He sustained a fracture of his right femur. The roentgenograms showed an intertrochanteric fracture with impaction near the base of the lesser trochanter and formation of moderate coxa vara. The inferior and posterior portion of the lesser trochanter was avulsed. External measurements showed 1 inch of shortening. Russell traction was applied. Examination on October 23, nine weeks after injury, showed firm clinical union, so traction was removed. Roentgenograms revealed apparent bony union. At the end of ten days, roentgenograms revealed no recurrence of the deformity, so the patient was allowed to use crutches but he was not permitted to bear weight. He returned to work on April 1, 1929, eight months after injury. Examination showed that he walked with a limp, although measurements showed equal length of the legs. Slight muscular atrophy was present. Motion of the knee and ankle was normal. Internal rotation of the hip was impaired 20 per cent, with 20 per cent impaired flexion.

CASE 18.—M. N., a man, aged 65, was injured on Dec. 5, 1929, when some scaffolding on which he was standing broke and he fell 14 feet to the pavement. He sustained a fracture of the right thigh and right forearm. The roentgenograms showed a pertrochanteric fracture of the femur with the greater trochanter avulsed and displaced slightly posteriorly. The line of fracture extended downward through the center of the shaft for a distance of about 1 inch beyond the lesser trochanter. There was moderate impaction of the fracture with slight external rotation of the distal fragment and varus deformity. Measurements showed 1 inch of shortening. Russell traction was applied with 8 pounds of weight. Examination on March 1 showed firm clinical union. The roentgenograms showed apparent bony union. Traction was removed, and the patient was allowed to remain in bed. Roentgenograms taken at the end of ten days showed no recurrence of the deformity, so the patient was allowed to use crutches but was not allowed to bear weight. Measurements showed the right leg to be 35 inches in length, and the left, 35¼ inches. Motion of the ankle was normal. Extension of the knee was complete, with flexion of 113/127. On August 1, the patient was bearing weight on his foot. The hip showed 40 per cent impairment of flexion with moderate impairment of internal rotation. Motion of the knee was practically normal; that of the ankle, normal. Measurements showed ¼ inch of shortening. Further disability was estimated at from three to four months, the total period of disability from the time of injury being about one year.

CASE 19.—J. B., a man, aged 52, was injured on April 1, 1929, when he fell through an opening in a floor about 20 feet, landing on the pavement. The roentgenograms showed an intertrochanteric fracture of the left femur. There was moderate separation of the line of fracture at the upper margin of the greater trochanter with impaction near the base of the lesser trochanter. There was considerable inward displacement of the entire shaft with the production of moderate coxa vara deformity. Measurements showed 1½ inches of shortening. Russell traction was applied with 8 pounds of weight. Examination on June 10, nine weeks after the accident, showed firm union. The roentgenograms showed

excellent position and alinement with evidence of bony union. Traction was removed. The patient remained in bed until June 24, when roentgenograms showed no recurrence of the deformity. He was allowed to use crutches and was referred for physical therapy. Roentgenograms taken July 15, showed complete obliteration of the line of fracture. The patient began to bear weight in August, 1929. He discarded his crutches on October 15, and was able to return to work on Feb. 1, 1930, ten months after the accident. Examination showed the limbs to be equal in length, the patient walking without a limp. Function of the knee and ankle joints was normal. There was slight limitation of internal rotation and flexion of the hip, but no apparent muscular atrophy.

Case 20.—A. V., a woman, aged 73, was injured on Oct. 15, 1929, when she fell in the dark over a chair and struck her left hip on the floor. She was immediately disabled and lapsed into a state of profound shock. The roentgenograms showed an impacted avulsion fracture of the greater trochanter of the left femur and an oblique intertrochanteric fracture with the fracture line extending into the shaft of the femur for 1 inch beyond the lesser trochanter. The shaft rotated externally. Measurements showed ¾ inch of shortening. Russell traction was applied with 8 pounds of weight. Roentgenograms taken on October 20 showed an improvement of position and alinement. Measurements of both extremities were equal. The patient, however, failed to rally; she died on November 9.

Case 21.—A. D., a woman, aged 60, was injured on March 10, 1930, when an automobile in which she was riding turned over as a result of a blowout of a tire. She was taken to a nearby hospital where temporary splints were applied; then she was transferred by ambulance to the California Hospital, Los Angeles. Examination showed marked deformity, swelling and false motion at the junction of the middle and upper thirds of the left thigh. There was 1¾ inches of shortening. The patient was suffering from chronic bronchitis. Roentgenograms taken March 11 showed: (1) a markedly comminuted fracture of the upper third of the left femur with complete displacement (the upper fragment was displaced inward and posteriorly) and (2) transverse fracture of the lower one third of the left femur with slight inward and posterior displacement.

Temporary splints were used until March 15, when the patient was transferred to her home, where the limb was placed in Russell traction with 8 pounds of weight. Clinical examination on May 29, eleven and one-half weeks after injury, showed firm union, so traction was removed. Motion of the ankle was normal. Extension of the knee was complete; there was 80 degrees of flexion. The patella was free. Measurements showed ¼ inch of shortening. On June 10, the patient was allowed up in a wheel chair, no recurrence of deformity having occurred. She was given crutches on June 21, and began light weight-bearing. Flexion of the knee was 112 degrees. On July 12, she walked with one crutch and cane. There was no pain at the site of the fracture. Flexion of the knee was 120 degrees. On August 1, about five months after injury, the patient was walking without support and doing regular housework. Motion of the ankle, knee and hip was practically normal. There was slight edema of the leg and ankle. The left limb was ¼ inch short, but the patient walked without a limp.

Case 22.—E. B., a man, aged 21, was injured on Aug. 12, 1930, when he slipped from the roof of a four story building and fell to the ground. He sustained fractures of both wrists, fracture of the transverse processes of the first and second lumbar vertebrae, together with a fracture of the left femur. Examination of the femur showed deformity, loss of function and acute tenderness to pres-

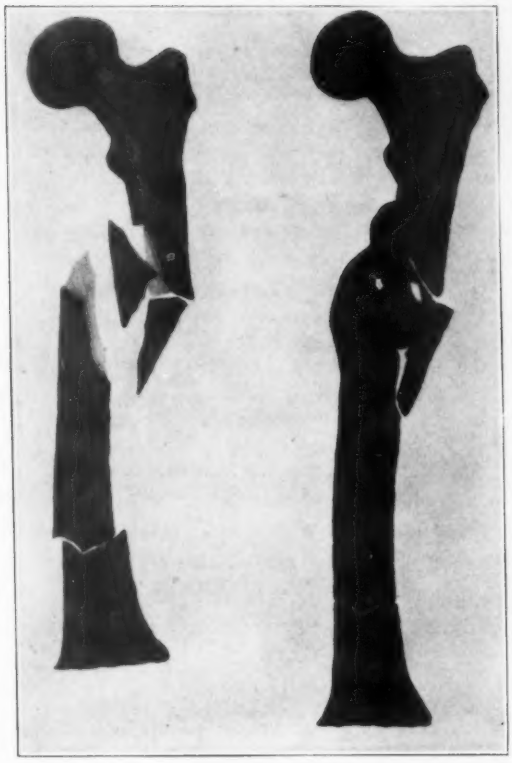

Fig. 15 (case 21).—Roentgenograms taken on March 11 and June 21, 1930, respectively.

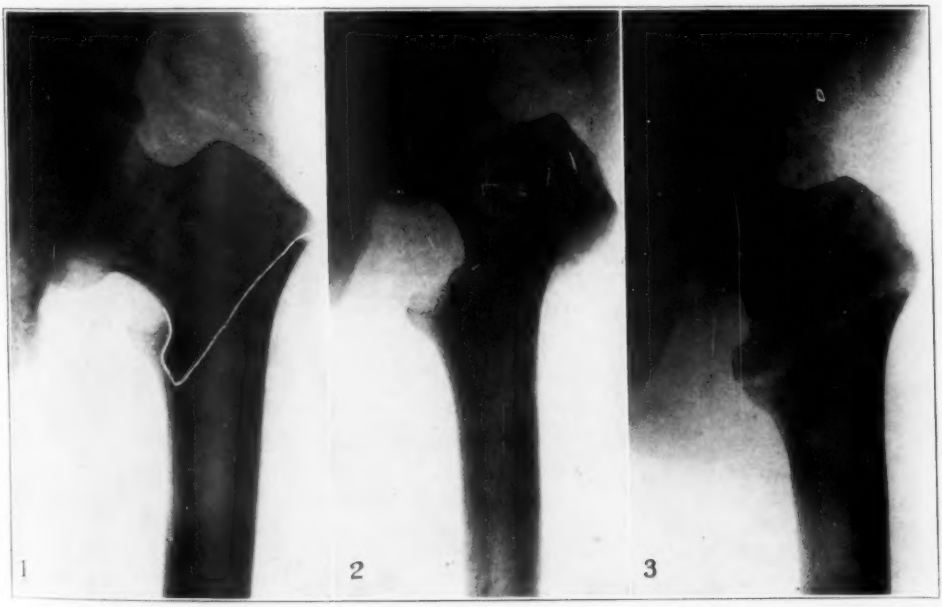

Fig. 16 (case 22).—Roentgenograms taken on: *1*, Aug. 12, 1930, showing degree of impaction; *2*, August 15, showing reduction of impaction with outward and upward displacement of the proximal fragment; *3*, August 16, showing almost perfect position and alinement.

sure in the region of the greater tuberosity. The greater tuberosity moved with the femur on rotation, and no crepitus was obtained. Measurements showed 1½ inches of shortening. Roentgenograms taken on August 12, showed a complete transverse pertrochanteric fracture of the left femur. The upper fragment was impacted into the lower. There was moderate diminution of the angle between the neck and the shaft. The patient was congenitally syphilitic.

Russell traction was applied with 8 pounds of weight with the limb in about 10 degrees of abduction. Roentgenograms taken on August 15 showed that the impaction had been entirely reduced. There was considerable outward and upward displacement of the proximal fragment. The limb was placed in 40 degrees abduction, the same amount of weight being used. Roentgenograms taken on August 16 showed almost perfect position and alinement.

Two patients with fractures of the acetabulum were treated by the Russell method, 6 pounds of weight being used; excellent results were obtained. This method was also employed on a child, aged 5, who had sustained a complete fracture of the left innominate bone with marked upward dislocation. Four pounds of weight was used, the dislocation was overcome, and a perfect result was obtained.

COMMENT

Twenty-one cases of fracture of the femur are reported. In case 3, a fracture of both femora was sustained; in case 21 a double fracture of the femur, so that the total number of fractures treated were twenty-three. Ridgely and Bongardt [3] reported the successful treatment of intracapsular fractures of the neck of the femur by this method, also epiphyseal separation of the lower end of the femur. Ryan [2] stated that the method is ideal for elderly patients who have sustained a fracture of the neck of the femur and in whom the Whitman reduction is not advisable.

Intertrochanteric Fracture.—Three patients with intertrochanteric fracture were treated, all over 50 years of age. The only mortality occurred in this group. The line of fracture followed the anterior oblique line, connecting the two trochanters. There was moderate impaction, the displacement consisting in flattening of the angle made by the neck of the shaft and resulting in the production of a coxa vara deformity.

The average period of traction was nine weeks, with hospitalization of twelve and one-half weeks. It was not necessary for the patients to wear supporting caliper splints. They began to bear weight four months after injury. The average period of disability was nine months. The limbs were equal in length. Slight muscular atrophy was present.

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3. Ridgely, I. O., and Bongardt, H. F.: Treatment of Fractures of the Femur by the Hamilton Russell Method Traction, Am. J. Surg. **7**:251 (Aug.) 1929.

Motion in the ankle and knee joints was normal. In one case, there was slight limitation of internal rotation and flexion at the hip.

Pertrochanteric Fractures.—Two patients with pertrochanteric fractures were treated. The line of fracture passed more or less transversely across the upper end of the femoral shaft, beginning on the mesial side above the lesser trochanter and terminating on the outer side below the great trochanter. The lesser trochanter was either attached to the distal fragment or was torn loose and formed a third fragment. Comminution was present, with moderate coxa vara deformity. In those cases in which the lesser trochanter is fractured and displaced, the Russell method is ideal, as the limb can be immobilized in a position of flexion and slight internal rotation, and relaxation of the detached ileopsoas muscle thereby obtained.

TABLE 4.—*Results in Cases of Intertrochanteric Fracture*

Case	Age	Traction	Hospital	Disability
17	57	9 weeks	12 weeks	8 months
19	52	9 weeks	13 weeks	10 months
20	74	Fatal		

TABLE 5.—*Results in Cases of Pertrochanteric Fracture*

Case	Age	Traction	Hospital	Disability
15	39	11½ weeks	14½ weeks	9 months
18	65	12 weeks	16 weeks	12 months

The average period of traction was twelve weeks, with hospitalization of fifteen weeks. Disability extended for ten and one-half months. The resulting shortening was ½ and ¼ inches, respectively. In both cases there was some limitation in the motion of the hip. Case 15, in which the lesser trochanter was separated from the shaft, showed an approximate 50 per cent loss of internal rotation. In this case there was severe comminution, and a caliper splint was used for four months after traction was removed.

Fractures of Proximal End Shaft of Femur.—Seven patients with this type of fracture were treated. In the majority of cases, the short proximal fragment was flexed and externally rotated. Those of the subtrochanteric type also showed some abduction. The longer distal fragment lay posteriorly and was drawn downward. The Russell type of traction tends to overcome the shortening and to lift the distal fragment and bring it into proper relation with the proximal one. If the upper fragment is abducted, the entire limb may be swung into abduction as well as being flexed and extended. A direct pull without abduction, however, tends to give the maximum restoration of alinement.

It was possible to reduce all these fractures. The average period of traction was twelve weeks; of hospitalization, fifteen weeks, and of disability, nine months. Healing was prolonged in case 5 due to a syphilitic infection. In case 9 there was severe comminution, and convalescence was prolonged by cardiac and renal disease. In three cases it was necessary to give added support with a caliper splint after traction was removed. Four cases showed some shortening—two ¾ inch and two ¼ inch. Motion of the ankle was normal. Case 9 showed 10 per cent loss of flexion of the knee due to prolonged immobilization together with interference of normal quadriceps function by the formation of new bone at the site of the fracture. In the same case there was con-

TABLE 6.—*Results in Cases of Fracture of the Proximal End of the Femur*

Case	Age	Traction	Hospital	Disability
1	17	9½ weeks	12 weeks	9 months
3	19	8 weeks	10 weeks	6 months
5	31	14 weeks	16 weeks	9 months
9	58	23 weeks	26 weeks	14 months
12	36	12 weeks	15 weeks	7½ months
16	34	6 weeks	10 weeks	9½ months
21	60	11½ weeks	Home	5 months

TABLE 7.—*Results in Cases of Fracture of the Middle Third of the Femur*

Case	Age	Traction	Hospital	Disability
2	54	9 weeks	12 weeks	7½ months
3	19	8 weeks	10 weeks	6 months
6	19	8 weeks	9 weeks	5½ months
7	25	13 weeks	16 weeks	10 months
8	22	9 weeks	12 weeks	9 months
10	63	12 weeks	14 weeks	8 months
14	24	Unable to reduce		

siderable stiffness at the hip joint, where the lesser trochanter had been comminuted and detached.

Fractures of the Middle Third of the Shaft of the Femur.—Seven patients with this type of fracture were treated. The displacement here did not depend as much on the muscular action as on the direction and action of the fracturing force. The distal fragment was usually posterior to the upper one. Outward angulation was seen when the ends of the fracture remained in apposition; inward displacement of the lower fragment was seen when the ends had slipped by. Indications for the traction method here were to overcome shortening and to apply side traction if lateral angulation was present. This group showed a disposition toward posterior sagging at the site of fracture.

In one of these cases it was not possible to reduce the fracture, and subsequent open operation showed interposition of muscles between the fractured ends. The average period of traction was nine weeks, with

twelve weeks of hospitalization. The period of disability averaged seven and one-half months. It was necessary for three of the patients to wear calipers for two and one-half months after the traction was removed. Two cases resulted in ½ inch of shortening. In three cases there was slight residual impairment of flexion of the knee, the maximum being 15 degrees in case 7 in which the period of immobilization was prolonged. Motion of the hip and ankle was normal.

Fractures of the Distal End of the Femur.—Four patients with this type of fracture were treated. The lower fragment here was tilted posteriorly by the action of the gastrocnemius. The distal end of the upper fragment showed a tendency to pass downward and forward toward the patella. None of the patients showed injury to the popliteal vessels, but one did show injury to the external popliteal nerve, as evidenced by inability to dorsiflex the foot or extend the toes, together with numbness over the dorsum of the leg. The Russell method in

TABLE 8.—*Results in Cases of Fracture of the Distal Third of the Femur*

Case	Age	Traction	Hospital	Disability
4	18	11 weeks	14 weeks	8 months
11	48	28 weeks	31 weeks	14 months
13	33	Unable to reduce		
21	60	11½ weeks	Home	5 months

these types of fractures overcomes the shortening and tends to correct the backward rocking of the lower fragment by flexion of the knee, thereby relaxing the gastrocnemius muscles.

In one of these cases the fracture was not reduced, owing to the interference of soft tissues. Case 4 resulted in ½ inch of shortening, but with normal function. In case 11 union was delayed, but normal function without shortening resulted.

The average amount of weight used in the reduction was 8 pounds, this being sufficient except in two cases in which it was necessary to add 3 pounds. In four cases side traction with 3 pounds was applied to overcome inward bowing. Posterior bowing was successfully prevented in all cases by the use of a soft pillow, which was placed immediately under the thigh at the site of fracture.

The duration of traction for all types of fractures of the femur averaged nine weeks, the shortest was eight weeks. Two cases of delayed union were seen in which firm clinical healing did not take place until after twenty-three and twenty-eight weeks, respectively. Both of these patients were treated with calcium and viosterol. In one case that was complicated by a syphilitic infection, antisyphilitic treatment was given and firm union occurred after fourteen weeks.

In three cases there appeared to be firm clinical union at the time of removal of the traction. These patients were allowed to move about freely in bed, but after a few days, they began to complain of pain and tenderness at the site of fracture. The roentgenograms showed a beginning recurrence of angulation, and traction was reapplied. One of these cases was complicated with syphilis; the other two showed delayed union.

The average period of hospitalization was twelve weeks; the shortest nine weeks, and the longest thirty-two weeks.

In eight cases it was thought advisable that the patient wear a walking caliper splint. These were cases in which there was delayed union or a severe comminution or in which the roentgenograms showed a relatively small amount of callus. The calipers were worn on an average of two and one-half months.

The average period of temporary disability was nine months; the shortest period five and one-half months, the longest fourteen months.

In evaluating the results obtained by this method, the triad of contour, union and function has been taken into consideration.

Contour in all cases was normal. There was no apparent bowing. One case showed a slight prominence over the dorsum of the thigh at the site of fracture, which was due to the formation of excessive callus. The muscles in two cases were somewhat atrophied. There was no apparent shortening, although in two of the cases the patients walked with a slight limp.

Union was obtained in all but two cases. Subsequent open operation showed that in both of these cases muscle tissue was interposed between the ends of the fracture. Firm clinical union usually occurred at from eight to ten weeks. No cases of fibrous union were encountered, though two were rather delayed in forming hardened callus.

Function in all cases was good. Five cases, one of them with a fracture of both femoral shafts, showed a return to absolute normal. There was no shortening in nine cases; two cases showed ¼ inch of shortening, four cases ½ inch and two cases ¾ inch. Motion of the ankle was normal in all cases. The knee showed complete extension in all cases. Flexion was somewhat impaired in six cases, the maximum amount being 15 degrees. Motion of the hip was normal in all but four cases, in which some impairment of internal rotation and flexion resulted. All of these patients had sustained severely comminuted fractures of the lesser trochanter with partial separation.

SUMMARY AND CONCLUSIONS

I have used practically all recognized methods of treatment in cases of fracture of the femur. I have obtained the best results by the use of the Russell traction apparatus. This method depends on a natural and

comfortable position of the limb with a minimum of weight whereby the equilibrium of the muscle is restored; with this restoration of muscle tone and position, the fractured ends of the bone will fall into a more or less natural alinement, provided there is no interposed tissue. One must bear in mind that an absolute restoration of anatomic position is not necessary for a good functional result. I have used the method as described by Russell with practically no change. The apparatus, its application and the after-care of the patient have been described. The results have been analyzed and the following deductions drawn:

1. The Russell method of traction is the method of choice in treating all types of fractures of the femur from the intertrochanteric to the lower epiphyseal regions.

2. It gives satisfactory position and alinement in all cases, except when muscle is interposed between the fractured ends.

3. It gives a minimum of permanent changes in the joint as compared with other methods.

4. The average period of traction in fractures of the femur is nine weeks, of hospitalization twelve weeks and of temporary disability nine months.

5. The method is inexpensive, easy to apply, comfortable to the patient and materially simplifies nursing care.

PAGET'S DISEASE

A PREDISPOSING FACTOR TO OSTEOGENIC SARCOMA *

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The frequent association of Paget's disease and osteogenic sarcoma in patients over 50 years of age has attracted the attention of other observers. Our interest was aroused because of three cases recently coming under our observation, and a careful study of the subject was undertaken. We would reiterate Codman's [1] suggestion that such cases deserve a separate division in the Registry classification because of their different clinical features. It seems to us also that this group may be important in giving a clue to one of the etiologic factors of osteogenic sarcoma. We know of no instance of the development of a benign giant cell tumor or endothelial myeloma occurring in a bone that was the site of a preexisting Paget's disease.

For a clear understanding of the problem, it has seemed advisable to summarize briefly some of the known facts concerning Paget's disease.

DESCRIPTION OF OSTEITIS DEFORMANS

Sir James Paget,[2] in 1877, first described the disease that bears his name. It is apparent that it is a constitutional disease, although it may manifest itself in a single bone; it more commonly involves a number of bones, and of these the skull is a favorite site. The condition is considered rare, although most writers agree that it probably occurs more frequently than is generally recognized, for it seems likely that it is often overlooked, especially when it attacks only the skull.

ETIOLOGY

While its etiology is still unexplained, numerous theories have been advanced. Arterial changes in the vessels of the extremities are often found, but as the disease occurs in persons of advancing years, this symptom may be of little significance. Probably the most engaging theory is that it is due to a defective metabolism of calcium, having as

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* From the Department of Bone Tumors, Memorial Hospital.

1. Codman, E. A.: Personal communication.
2. Paget, James: M. Chir. Tr. **60**:37, 1877; Illust. M. News **2**:181, 1889.

its underlying basis a faulty function of the parathyroid glands. Much recent work has tended to show that cases of von Recklinghausen's disease (osteitis fibrosa cystica) are associated with a high rate of excretion of calcium, and in a number of instances abnormal changes have been noted in the parathyroid glands. The similarity, in many respects, of Paget's and von Recklinghausen's diseases leads one to the view that both may have their origin in some disorder of the parathyroids as yet little understood. Further investigation is needed along these lines and may be productive of real information; moreover, it is not beyond the bounds of reasonable hope that endocrine therapy may offer something of value in the treatment for osteitis deformans, an achievement not hitherto attained.

GROSS APPEARANCE

The changes in the bone seen in Paget's disease are characteristic and are the result of a combination of destruction of bone and formation of new bone. The latter, however, does not consist of normal bone, but of osteoid tissue. Changes in the shape, size and structure of the bone occur. The medullary cavity is encroached on, and in advanced cases it is often impossible to state where the cortex ends and the medulla begins. The skull, spine and the long bones of the lower extremity are most frequently affected. The microscopic pathology will be considered in some detail when the association with osteogenic sarcoma is discussed.

SYMPTOMS AND SIGNS

Bowing of the lower extremities occurs, due to the effect of the bearing of weight, and the resulting deformity is one of the characteristic features of the disease. In other cases, however, the increase in the size of the head is the first symptom noted. Pain in the legs is an inconstant and often transitory symptom; it may disappear entirely as the disease progresses. Fractures sometimes occur in bones affected by the changes of Paget's disease, but union generally results. One of us has observed two cases in which there were fractures of the tibia and one case showing fracture of the humerus, with healing in each instance.

DIAGNOSIS

The diagnosis is not difficult if the condition is suspected and roentgenograms are made, because the changes in the bone as revealed by x-ray films are rather characteristic. Occasional cases of metastasis to bone from carcinoma are seen in which the picture of Paget's disease is closely simulated; of these, prostatic carcinoma is apt to be the most confusing. In the absence of a demonstrable primary growth

elsewhere, the diagnosis of Paget's disease is rendered more certain. While typical cases of osteitis deformans are readily distinguishable from typical cases of osteitis fibrosa cystica, there are certain borderline cases in which the distinction may be difficult. Roentgenograms of a typical case of osteitis deformans showed marked osteosclerosis and osteoporosis in adjacent areas. The degree of osteosclerosis that follows the porosis varies considerably in individual cases.

Garland [3] concluded that the two conditions are histologically and anatomically identical. While this may be true, when one analyzes the histogenetic process involved, one finds that in both instances there is a fibrous proliferation with formation of new bone and, therefore, a process of repair or healing. These factors seriously attack the claim of osteitis fibrosa to consideration as a pathologic entity. This same process is also found about the walls of abscesses, bits of capsule from central sarcoma of bone, or secondary metastatic tumors and periosteum overlying ossifying hematoma, which further emphasizes it as a process of repair or a defensive reaction of both cancellous and cortical bone, as well as of the periosteum. The persistence of cystic formations both in Paget's disease and in osteitis fibrosa cystica (single and multiple cysts of the bone) is due to the difficulty that nature has in collapsing a cavity with rigid walls.

While the etiology of Paget's disease is unknown, there is certainly a different process at work in this disease than that in osteitis fibrosa cystica. In 2 per cent of the cysts of the bone, the destructive process of the bone was found to be stimulated by foreign bodies; in 20 per cent, rather loosely classed as osteitis fibrosa, some primary disease such as osteomalacia, fragilitas ossium or disturbances of the parathyroid gland with rarefaction and the formation of cysts in the bones has been responsible for the reaction of the bone. In 78 per cent, representing solitary cysts of the bone, a definite relation has been established between cyst of the bone and giant cell tumor. (These figures are supplied by Dr. Copeland from records at Bloodgood's Clinic.)

Osteitis deformans occurs in patients who have reached middle or late life and presents an entirely different prognosis and response to treatment than that presented by osteitis fibrosa cystica, which occurs for the most part before the twentieth year, frequently shows spontaneous remissions and is often cured by pathologic fracture or surgical intervention. Paget's disease is progressive and up to the present time has been found unresponsive to any form of treatment.

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3. Garland, L. H.: Am. J. Roentgenol. **22**:517 (Dec.) 1929.

It is our belief that if roentgenograms of the skull were made more generally of patients over 50 years of age it would be found that osteitis deformans is much less rare than it is thought to be. We now make it a practice to obtain films of the skull on all patients in the Bone Tumor Clinic over the age of 50. As mentioned previously, there has as yet been no accepted specific treatment for Paget's disease.

PAGET'S DISEASE ASSOCIATED WITH SARCOMA OF THE BONE

In his earliest communication concerning the disease that bears his name, Paget mentioned the tendency in patients with osteitis deformans to develop neoplastic conditions. In his twenty-three personally observed cases, we learn from a subsequent report that of the eight patients who were traced to their deaths, malignant diseases developed in no less than five.

Delafield [4] maintained that the incidence of sarcoma among patients with Paget's disease is no greater than in any group of persons of the same age. This is contrary to the opinions of the majority of observers and it seems to be now firmly established that, at least as regards the occurrence of osteogenic sarcoma, Paget's disease is a predisposing factor.

Packard, Steele and Kirkbride [5] reviewed the literature up to 1901 and collected 66 cases of undoubted osteitis deformans in which there was an associated sarcoma in 5, or 7.5 per cent. DaCosta,[6] in 1914, assembled 213 cases in which sarcomatous diseases of some form developed in 9.5 per cent. Gruner, Scrimger and Foster [7] reported that in about 9 per cent of their cases of Paget's disease this condition was associated with sarcoma.

When a condition as relatively rare as Paget's disease comes to be associated with a second condition as uncommon as osteogenic sarcoma, one cannot but seriously consider that this association is more than one of mere chance or coincidence. In one year Camp [8] observed 2 cases of sarcoma in Paget's disease at the Massachusetts General Hospital. Locke [9] found that 4 of his 65 patients with osteitis deformans had osteosarcoma or fibrosarcoma (6.2 per cent).

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4. Delafield, in Delafield and Prudden: Textbook of Pathology, ed. 14, New York, William Wood & Company, 1927, p. 447.

5. Packard, F. A.; Steele, J. D., and Kirkbride, J. S.: Am. J. M. Sc. **122**: 252, 1901.

6. DaCosta, J. C.; Funk, E. H.; Bergeim, O., and Hawk, P. B.: Pub. Jefferson M. Coll. & Hosp. **6**:1, 1915.

7. Gruner, O. C.; Scrimger, F. A. C., and Foster, L. S.: Arch. Int. Med. **9**:641 (June) 1912.

8. Camp, J. D.: Radiology **5**:495 (Dec.) 1925.

9. Locke, E. A., quoted by Bird: Personal communication.

Bird [10] studied the records of four large Boston hospitals with some interesting results. He was able to collect records of 64 patients with osteitis deformans, in 7 of whom (approximately 11 per cent) sarcoma occurred. He estimated that there is 1 case of Paget's disease in every 15,000 admissions to hospitals in Boston. This corresponds closely with the report [11] of 1 in 10,000 at the Johns Hopkins Hospital; 1 in 13,000 at Jefferson [6] Hospital, and 1 in 16,000 at the Mayo Clinic.[12] At the Peter Bent Brigham Hospital there were 15 cases of osteitis deformans in 45,000 admissions, or 1 in 3,000. This, Bird explained on the theory that a far larger percentage of patients in that hospital had roentgenograms taken (89 per cent). The disease is probably not as rare as the figures from the various hospitals would suggest. In the first place, many patients do not enter hospitals unless some complication arises and even then they may be classified on the records of the hospital according to the complication and not be indexed as having Paget's disease. Moreover, as Bird stated, early examples of the disease are being constantly overlooked, especially when it is confined to 1 bone.

Of the 9 cases of Paget's disease in which there was an accompanying sarcoma, Bird stated that 8 were fatal, the remaining case being untraced. The average duration of life after the first evidence of sarcoma was eight months; the shortest, two and a half months, and the longest one year. In 5 of these 9 cases, there was pathologic verification in the diagnosis of sarcoma. The duration of the Paget's disease prior to the development of sarcoma is mentioned in 6 of the 9 cases. In 1 case, the period was three years; in another, ten; in another, eleven; in 2 cases, fifteen years, and in 1 instance, twenty years.

An interesting report of a case (Cabot,[13] case 12513) is that of a man, aged 43, with a history of pneumonia eight years before admission, followed by a painful condition of the left leg, which was noted during convalescence. A few months prior to admission the pain increased in severity. There had been an associated decline in the general health of the patient during the last few years. He was admitted with a transverse fracture of the distal portion of the neck of the left femur, which occurred while he was at work, but without any history of violence, either direct or indirect. The Wassermann reaction was negative. Roentgen examination showed evidence of osteitis deformans in

10. Bird, C. E.: Sarcoma Complicating Paget's Disease of Bone; Report of Nine Cases, Five with Pathologic Verification, Arch. Surg. **14**:1187 (June) 1927.
11. Hurwitz, S. H.: Bull. Johns Hopkins Hosp. **24**:263, 1913.
12. Carman, R. D., and Carrick, W. M.: J. Radiol. **2**:7 (April) 1921.
13. Cabot: Boston M. & S. J. **195**:1215 (Dec. 23) 1926.

the left femur, skull, dorsal spine, ribs, scapula, clavicle and bones of the forearm. A pathologic fracture of the neck of the femur was treated by immobilization in a plaster spica, and later it became evident that there was a rapidly growing tumor involving the site of the fracture. Biopsy was performed, and roentgen therapy was administered. The patient lived eight months after admission to the hospital. Autopsy was performed and showed osteitis deformans and osteogenic sarcoma of the left femur with metastasis to the skull and brain.

Von Albertini [14] described in minute detail the development of sarcoma in a case of Paget's disease. His patient was known to have had osteitis deformans of the left femur and tibia for five years. The patient subsequently developed a tumor of the femur for which amputation of the thigh was performed. Examination of the specimen showed that both the femur and the tibia were the seat of Paget's disease and osteogenic sarcoma. The patient survived amputation but two months and exhibited evidence of metastasis to the liver and local recurrence in the stump at the time of his death. Autopsy revealed a thrombotic tumor in the left common iliac vein extending into the inferior vena cava, also metastases to the lungs, epicardium, bronchial and retroperitoneal lymph nodes, kidney and liver. Excellent photomicrographs showed the histologic appearance of the osteitis deformans, presarcomatous changes in certain areas and, in other places, actual sarcoma. Von Albertini remarked that a long-standing osteitis deformans constitutes a presarcomatous condition.

Gold [15] described the case of a man, aged 63, who had broken his arm twenty-three years and ten years previously; there was a tumor destroying from 8 to 10 cm. of the proximal portion of the humerus. Roentgen examination gave evidence of Paget's disease. Histologic examination showed the sarcoma to be of the round cell type.

Our study includes a total of 71 cases of osteogenic sarcoma in patients over 50 years of age. Twenty cases were collected from the records of the Memorial Hospital and 51 were from the Bone Sarcoma Registry. As shown in table 1, the association of osteogenic sarcoma and Paget's disease is relatively the same in the two series. The percentage in the series from the Memorial Hospital was 30 and in that from the Bone Registry it was 27.4, with a percentage of 28 for the total number. Such a frequent association of two apparently dissimilar diseases justifies a careful study of the features presented in the different cases.

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14. von Albertini, A.: Virchows Arch. f. path. Anat. **268**:259, 1928.

15. Gold, H.: Wien. med. Wchnschr. **77**:1700, 1927.

The cases of all patients over 50 years of age with osteogenic sarcoma were studied. As shown in table 2, the incidence of osteogenic sarcoma decreases in frequency in each half-decade age-group over 50 years. The oldest patient with osteogenic sarcoma whose case was on record in the Bone Registry was 77 years of age, and in this patient the sarcoma was not associated with Paget's disease. In the series from the Memorial Hospital there are no cases of Paget's disease complicated by osteogenic sarcoma in patients under 50 years of age. This in itself is an important feature and it is further emphasized in

TABLE 1.—*Association of Osteogenic Sarcoma and Paget's Disease* *

	Memorial Hospital	Bone Sarcoma Registry	Total
Number of patients over 50 years of age with osteogenic sarcoma	20	51	71
Number of patients over 50 years of age with osteogenic sarcoma and Paget's disease	6	14	20
Percentage of cases with two diseases associated	30	27.4	28.1

* Case E. S. in the series from the Memorial Hospital is also included with the cases from the Bone Registry.

TABLE 2.—*Decrease of Frequency in Incidence of Osteogenic Sarcoma in Patients Over 50 Years of Age* *

Ages by Half Decades	Patients with Osteogenic Sarcoma Alone	Patients with Osteogenic Sarcoma and Paget's Disease
50 to 55	18	1
55 to 60	13	6
60 to 65	8	5
65 to 70	7	6
70 to 75	5	2
75 and over	1	0

* There are, however, four cases in the Bone Sarcoma Registry of osteogenic sarcoma associated with Paget's disease in patients under the age of 50. Three of the patients were men and one was a woman. Their ages were 35, 37, 42 and 47.

table 2. In the half-decade age-groups, the highest percentage is found in persons between 65 and 70 years, in which six of the seven, or 85.7 per cent, of the patients with osteogenic sarcoma had Paget's disease. The percentages decrease above and below this peak.

Osteogenic sarcoma appears slightly more common in men than in women (29 men, 22 women). This is substantiated by a series of 121 osteogenic cases studied by the authors in which there were 74 men and 47 women. In the series with Paget's disease and osteogenic sarcoma, men were affected over five times more frequently than were women (17 men, 3 women). This may be due to the fact that the diagnosis of Paget's disease is made more often in men than in women and, to a lesser extent, it may be due to the increased susceptibility of men to osteogenic sarcoma.

The sites of predilection of osteogenic sarcoma in the skeleton in patients over 50 years of age correspond closely to those found at any age except for the increase in frequency of involvement of the flat bones, as shown in table 3. Involvement of the scapula is particularly common, appearing in nine of the fifty-one cases, although Paget's disease was not associated in any of these cases. Approximately 60 per cent of the osteogenic sarcomas of the tibia, humerus and ilium and 100 per cent of the cases of osteogenic sarcoma of the skull occurred on the basis of a preexisting Paget's disease. Therefore, in a patient over 50 years of age, presenting an osteogenic sarcoma of the skull, there is a strong probability of an associated Paget's disease.

In our series, when Paget's disease was present it was demonstrated by roentgen examination in the bone involved by the osteogenic sarcoma,

TABLE 3.—*Location of Primary Tumor*

	Long Bones											Flat Bones			
	Femur	Humerus	Tibia	Ulna	Mandible	Radius	Clavicle	Fibula	Rib	Metacarpal	Vertebra	Scapula	Ilium	Skull	Ischium
Osteogenic sarcoma in all patients over 50 years of age	28	8	6	2	2	1	1	1	1	1	1	9	5	2	2
Osteogenic sarcoma and Paget's disease in patients of the same group over 50 years of age	6	5	4	0	0	0	0	0	0	0	0	0	3	2	0

and in no instance was the sarcoma found to affect a portion of the skeleton free from roentgenographic evidence of Paget's disease.

The duration of Paget's disease before the appearance of osteogenic sarcoma is difficult to determine either by the history or by the physical examination. The patient may have had Paget's disease many years before attention was attracted to the insidious changes taking place. This is particularly true in women. However, Paget's disease is rarely reported in patients under 30 years of age and seldom in patients under 40 or 45 years. This is important, as osteogenic sarcoma is not found to complicate Paget's disease until the age-group of from 55 to 60 is reached. It seems highly probable that an interval of from ten to fifteen years is present between the final period for the onset of Paget's disease and the appearance of a complicating osteogenic sarcoma. In the histories we find this partially substantiated. Only five of the patients were aware of Paget's disease with its deformities. Two of these gave a positive history of a duration of eight years; one, "many years"; one, ten years, and one, twenty years. One of these

patients was under our observation for ten years with Paget's disease and developed an osteogenic sarcoma at the distal end of the humerus. The question may be raised of the possibility of two or more osteogenic tumors arising on the basis of Paget's disease in one patient. This was demonstrated in two patients in the series from the Memorial Hospital (cases 1 and 11). The assumption that the tumors were primary seems analogous to that of multiple independent squamous cancers arising on leukoplakia. Ordinarily, osteogenic sarcoma infrequently metastasizes to bone.

DURATION OF LIFE

The duration of life from the onset of the osteogenic sarcoma to death in patients with and without Paget's disease is relatively the same in the group from the Memorial Hospital, as shown in table 4. In considering the total number of cases, one finds that patients with

TABLE 4.—*Duration of Life*

	Patients with Osteogenic Sarcoma		Patients with Osteogenic Sarcoma and Paget's Disease	
	Number	Average Number of Months	Number	Average Number of Months
Memorial Hospital.....	10	18.7	4	16.0
Bone Registry.....	23	26.3	11	14.4
Total.....	33	24.0	15	14.8

osteogenic sarcoma and Paget's disease die approximately ten months earlier than patients with osteogenic sarcoma alone.

DIFFERENTIAL DIAGNOSIS

Paget's disease with an associated sarcoma must be distinguished from: (1) metastatic tumors of the bone (osteogenic sarcoma; the myelomas); (2) metastatic carcinoma of undetermined origin, especially prostatic carcinoma; (3) Paget's disease combined with syphilis of the bone or chronic infection, and (4) atypical cases of osteitis fibrosa cystica, multiple form, with the formation of giant cell tumors.

HISTOLOGY

The histologic picture of Paget's sarcoma differs from that seen in uncomplicated osteogenic sarcoma. It is of interest to quote from the opinions of several of the pathologists on case 772 of the Registry, which is case 11 of the series from the Memorial Hospital.

. . . one of the vagaries that occurs among the malignant tumors developing in Paget's disease. It seems to me that these cases should have a separate

division in the Registry classification, for they represent a different clinical entity from the usual osteogenic sarcoma. Some day this group may be particularly important in giving a clue to the origin of sarcoma.

Another writes:

This is not a typical osteogenic sarcoma. It belongs essentially among the variants of giant-cell tumors. It shows a great many giant cells, but many of these are mononuclear and hyperchromatic. The main cell is large and polyhedral. There is much lymphocytic infiltration. In men over 50 years of age and especially in patients with osteitis fibrosa, giant cells tend to recur locally and become malignant.

Five others simply report osteogenic sarcoma in Paget's disease.

The presence of giant cells in this tumor should not lead to the belief that the condition is benign. These giant cells differ from those found in epulis tumors. They are usually hyperchromatic and not necessarily multinuclear. Their exact relation to Paget's disease is not well understood.

PROGNOSIS

The 100 per cent mortality rate of patients with the two diseases may be explained on several grounds. In the first place, patients who are accustomed to the "growing pains" associated with Paget's disease are not apt to seek medical advice as soon for a change in the character of the pain as patients with osteogenic sarcoma unassociated with Paget's disease; in the second place, the pathologic changes due to Paget's disease may delay the onset of the pain from an osteogenic sarcoma, and last, osteogenic sarcoma arising in Paget's disease may have more malignant qualities than this primary tumor of the bone in normal patients past middle life.

In the group from the Memorial Hospital, irradiation was done in four of the six cases in which the two diseases occurred; amputation was done in two cases, and in one case the disease was too far advanced for any treatment. Amputation was performed in twelve of the fourteen cases from the Bone Registry. We have been unable to find any record of a case of osteogenic sarcoma associated with Paget's disease in which the patient has suvived a period of five years.

TREATMENT

It would appear that some change from the ordinarily accepted methods of treatment is worthy of trial. In one of our cases (case 3), the patient was subjected to heavy external radiation by radium pack and exposure to high voltage x-rays, and amputation was performed about six months later. He received injections of the mixed toxins

of erysipelas and *Bacillus prodigiosus* following operation. These injections were given intravenously and were accompanied by severe reactions.

It may be that the use of preliminary radiation and of treatment with toxin following amputation will prove less disappointing than amputation alone.

REPORT OF CASES

CASE 1.—*Osteogenic Sarcoma Complicating Paget's Disease.*

History.—A man, aged 63, was admitted to Memorial Hospital on Aug. 26, 1928. The condition had begun nine months prior to admission with initial symptoms of stiffness and pain in the left knee. Five months later, he noticed a swelling in this location. He was treated with baking and massage under the assumption that the condition was rheumatism, but no relief was obtained, the pain growing steadily worse and the swelling becoming progressively larger. Early in July he was admitted to the Hospital for Joint Diseases, where a diagnosis of Paget's disease was made. There was no pain or swelling in any other part of the body; there was little loss of weight. There was no history of specific antecedent trauma. His immediate family history was negative for malignant diseases. He had been able to work steadily for about four months prior to his admission to Memorial Hospital.

Physical Examination.—The patient was a wiry male, aged 63, well developed and nourished, although showing slight loss of weight. Examination of the head revealed several bony enlargements and irregularities of the skull. These were discrete on palpation, but not painful. There were several other smaller and more questionable areas. The pupils were equal and reacted to light and accommodation. The teeth were replaced by dentures. The gums were smooth and there were no ulcerations. The mucous membrane was normal. The tonsils were enlarged, protruding into the pharynx; there was no apparent involvement. The tongue was normal. There were no enlarged glands in the neck. On inspection of the trunk, there was obvious distortion of the clavicles, more pronounced on the left side. The heart and lungs were essentially normal, except for some dulness in the base of the right lung with increased breath sounds and a slight systolic murmur transmitted toward the left axilla. The abdomen showed inguinal hernia on the right side. The rest of the examination gave negative results. The examination of the extremities was of special interest. The left upper extremity was apparently normal. The right elbow and lower part of the humerus showed a distinct enlargement, which was diffuse and not sharply outlined above. There was an enormous tumor of the lower part of the left thigh which entirely obliterated the anatomic markings of the knee. It occupied the anterior and middle aspects of the lower part of the thigh and extended less than half way up the thigh. The skin was shiny and discolored in areas, being dark bluish red and blotchy in appearance. There was some dilatation of the superficial veins of the skin. The lower part of the leg was diffusely swollen, owing to lymphatic and venous obstruction, and presented an appearance similar to elephantiasis. The lower part of the right leg showed a profound alteration of the normal subcutaneous outline of the tibia. There was the characteristic bowing seen in Paget's disease. On September 6, measurements showed that the circumference of the left limb at the patella was 25¼ inches (64.095 cm.) and that of the right limb 15¼ inches (38.175 cm.).

Roentgen examination of the femora, pelvis, spine, skull and chest revealed the characteristic features of Paget's disease. A roentgenogram of the left knee revealed extensive destruction of the inner tuberosity of the humerus with calcareous deposits in a huge soft mass. The Wassermann examination was negative.

Clinical Diagnosis.—A clinical diagnosis of Paget's disease with osteogenic sarcoma of the left femur and questionable metastasis of the right humerus was made. This was supported by the results of the roentgen examination. The disease was so far advanced that amputation was felt to be out of the question.

Fig. 1.—Sarcoma of the left femur. Paget's disease is evident in the right tibia.

Moreover, the tumor was so huge that toxemia from absorption of broken-down tumor tissue was about all that could be reasonably expected to result from treatment with x-rays or with radium. Therefore, no treatment of any kind was advised.

Laboratory Examination.—The Wassermann test of the blood was negative. The urine showed traces of albumin and casts. The blood count on admission was: hemoglobin, 55 per cent; red blood cells, 2,720,000; white blood cells, 10,000; polymorphonuclears, 81 per cent. No abnormal cells were noted.

On August 30, there was 10.3 mg. of calcium per hundred cubic centimeters in the blood.

Comment.—The histologic report in this case is of interest, showing as it does stages coexistent in the bone marrow ranging by gradual gradations from simple chronic inflammatory changes into definite osteogenic sarcoma. The fact that five months elapsed in this case between the initial pain and the development of a swelling emphasizes the importance of early roentgenologic examination in persons with persistent pain in the bone. It is worthy of note that a diagnosis of Paget's disease was not made until the patient already had an osteogenic

Fig. 2.—Roentgenogram showing sarcoma of the left femur.

sarcoma. It would seem to be important to caution the members of the medical profession concerning the need for careful observation in all persons with Paget's disease because of the potential danger of subsequent development of an osteogenic sarcoma.

CASE 2.—*Osteogenic Sarcoma of the Lower Part of the Right Tibia Complicating Paget's Disease.*

History.—A man, aged 68, was admitted to Memorial Hospital on June 23, 1927. In February, 1924, he had sustained an injury to his back and legs in an

automobile accident and remained in bed for ten weeks. During that time he noticed swelling, pain and discoloration of the upper third of the right tibia. In March, 1925, one year after the accident, a biopsy was done and the pathologic report showed a malignant tumor of the bone on the basis of a preexisting Paget's disease. Amputation was performed shortly thereafter. About two years elapsed without symptoms and in May, 1927, he was referred to us with symptoms of severe pain in the right forearm and total disability of the arm.

Physical Examination.—Examination showed a man in rather poor general condition. Examination of his lungs disclosed crepitant râles over both sides of

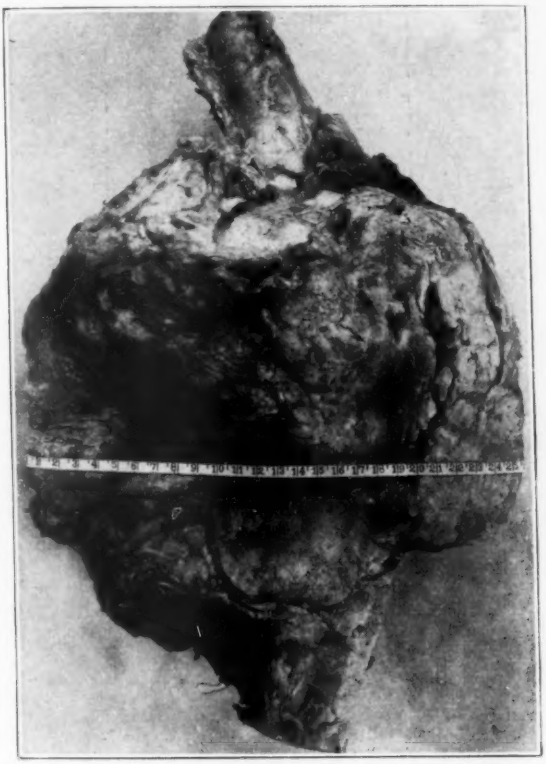

Fig. 3.—Gross appearance of the tumor (autopsy).

the chest posteriorly, especially at the base. This condition did not disappear on coughing. There were many small pigmented areas of skin on the back. The right leg had been amputated at the junction of the middle and upper thirds with no local recurrence. There was swelling of the right forearm more marked on the ulnar aspect.

Roentgen examination on July 20 showed extensive destruction of the upper half of the right humerus and the upper half of the ulna.

On June 11, a roentgenographic report had showed no evidence of metastasis to the chest.

Treatment.—The patient was given radium element pack for 25,000 millicurie hours at a distance of 10 cm. over the right forearm posteriorly, and one exposure

of high voltage x-rays. The upper half of the right humerus also received one treatment with high voltage x-rays. Thirteen injections of the mixed toxins were also given. The treatments were not followed by any demonstrable improvement and the patient was discharged on July 28, after a five weeks' stay in the hospital. He died one month later.

CASE 3.—*Osteogenic Sarcoma of the Left Humerus Complicating Paget's Disease.*

History.—A man, aged 57, about two months prior to admission began to have pain in the left shoulder, which he attributed to a sprain in the course of his occupation as a chauffeur of a passenger bus. He rubbed the painful area with liniment and later consulted a doctor for another condition, casually mentioning the pain in his shoulder. Roentgen examination was then made, and a diagnosis of probable sarcoma of the humerus was rendered. No mention was made at this time of Paget's disease. There had been a loss in weight of from 15 to 20 pounds (6.8 to 9 Kg.) in the last year. The patient had never had any serious illnesses. He had lost no time from his work on account of illness in the past thirty years. For many years, however, he had had cramplike pains in the legs at night (suggestive of Paget's disease).

Fig. 4.—Roentgenogram of the tibia of a patient with Paget's disease and osteogenic sarcoma, with the later development of a second osteogenic sarcoma of the ulna.

Physical Examination.—The patient was a well developed, poorly nourished man, about 60 years old, with marked tortuosity of the temporal arteries. The skull showed a number of irregular bosses, and an increase in the transverse diameter. The nose was normal. The teeth were completely replaced by dentures. The tongue was clean. The neck showed no palpable masses, scars or abnormal pulsations. The chest was symmetrical and expansion was equal. The costal angle was acute and there was a slight Harrison's groove. The lungs were resonant throughout. The abdomen was normal. There was a marked anterior bowing of the right femur and tibia which was obvious both on inspection and palpation.

Fig. 5.—Paget's disease of the skull.

Roentgenograms were made and the following report was rendered by Dr. Herendeen on July 26, 1929:

"Roentgenograms of the skull, left femur, pelvis and tibia reveal the characteristic features of Paget's disease. Stereoscopic views of the left shoulder reveal the presence of the same process in the clavicle, scapula and humerus. In addition, a large area of destruction of the bone is noted in the outer, upper third of the shaft of the humerus."

A second report, on September 11, was as follows: "A film of the lungs does not show definite evidence of metastases."

Treatment.—Treatment was commenced on August 9 and in four days the patient received four treatments with radium element pack for a total of 16,000 millicurie hours at a distance of 6 cm. On August 7, August 10 and September 12, he received three treatments with high voltage x-rays, each exposure lasting twelve minutes and consisting of 175 kilovolts given at a distance of 50 cm. from

Fig. 6.—Paget's disease of the tibia.

the skin, at a milliamperage of 30 through a port 10 by 10 cm. in size, the filtration being 0.5 mm. of copper, and all treatments being given to the left shoulder.

During these treatments and thereafter his arm was immobilized in a sling and a swathe. He returned to the outpatient department of the Bone Clinic for frequent observation. The pain became progressively more severe, and the tumor grew. That this represented continued growth of the sarcoma should not be assumed, as the effect of radiation on an osteogenic sarcoma is often to produce

swelling. However, the patient was unable to tolerate the pain and finally consented to amputation. It was necessary to perform an interscapulothoracic disarticulation because of the extent of the growth. This was done on Feb. 6, 1930. The patient made a smooth recovery following the initial shock which was forestalled in large measure by a transfusion given on the table at the end of the operation. Twelve days postoperatively, the injections of toxin were commenced, and ten were given. The wound healed promptly without infection. The patient was discharged on March 7, and has been observed regularly in the clinic. He

Fig. 7.—Paget's disease of the humerus with osteogenic sarcoma.

was last seen on November 13, nine months after amputation. At that time he was free from symptoms and showed no evidence of disease and a roentgenogram of the chest showed no evidence of metastases.

CONCLUSIONS

1. From a study of cases of osteogenic sarcoma in Memorial Hospital, it was found that in no patient was this condition associated with Paget's disease prior to the age of 50.

2. In a collected series from Memorial Hospital and the Bone Registry of seventy-one cases of osteogenic sarcoma in patients over

50 years of age, Paget's disease was found to be a predisposing factor to osteogenic sarcoma in 28 per cent.

3. Of patients with the two diseases associated, men are affected five times more frequently than women.

4. In general, it may be said that osteogenic sarcoma in patients over 50 has the same sites of predilection as in younger persons.

5. A patient over 50 with osteogenic sarcoma of the skull presumably has Paget's disease.

6. When osteogenic sarcoma is associated with Paget's disease, it invariably develops in a bone showing the characteristic changes of Paget's disease rather than in an otherwise normal bone.

7. Evidence is presented to show that Paget's disease is present from ten to fifteen years or more prior to the development of a complicating osteogenic sarcoma.

8. The duration of life is shortened by the association of osteogenic sarcoma with Paget's disease, as determined by a comparative study of a group of patients of the same age without osteogenic sarcoma.

9. No record has been found of the survival for five years of a patient with osteogenic sarcoma and Paget's disease under any method of treatment.

10. Paget's sarcoma has proved to be relatively resistant to radiation.

11. Preliminary radiation by intensive exposure to radium pack and high voltage x-rays and, following amputation, the use of prophylactic constitutional therapy with the mixed toxins are suggested as a method worthy of trial.

THE MECHANISM OF THROMBOPHLEBITIC EDEMA*

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PREVIOUS LITERATURE

The mechanism of the edema that follows thrombophlebitis of the extremities has provoked considerable discussion for many years. Repeated experimental investigations have tended to support first the theory of venous obstruction, then that of lymphatic origin, without having served to bring the problem to definite decision. Many years ago, Cohnheim [1] showed that ligation or extirpation of all of the lymphatics from an extremity fails to produce edema of that limb. These experiments have been repeated many times since then, with numerous variations, and usually with the same results. Clinical observations, however, of edemas following mechanical extirpations of lymph nodes or the compression of the lymphatics by tumor growth have given constant support to the belief that lymphatic obstruction will sufficiently interfere with the return of fluid to result in edema of the extremity. The clinical improvement noted after surgical procedures intended to provide new lymphatic pathways from edematous limbs, such as Handley's lymphangioplasties,[2] and the Lanz [3] and Kondoleon [4] operations, which are directed toward providing anastomoses between the

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3. Lanz, Otto: Eröffnung neuer Abfuhrwege bei Stauung im Bauch und unteren Extremitaeten, Zentralbl. f. Chir. **38**:153, 1911.

4. Kondoleon, E.: Die operative Behandlung der elephantiastischen Oedeme, Zentralbl. f. Chir. **39**:1022, 1912; Zur Frage der Lymphdrainage bei elephantiastischen Oedemen, ibid. **50**:443, 1923. Sistrunk, W. E.: Further Experiences with the Kondoleon Operation for Elephantiasis, J. A. M. A. **71**:800 (Sept. 7) 1918. Matas, Rudolph: The Surgical Treatment of Elephantiasis and Elephantoid States Dependent upon Chronic Obstruction of the Lymphatic and Venous Channels, Am. J. Trop. Dis. **1**:60, 1913.

superficial and deep sets of lymphatics, has given further support to the lymphatic theory.

Attempts to produce edema experimentally by ligation of the veins go back to the researches of Lower, in 1680.[5] He succeeded in producing edema in various parts of the body by tying the veins, but subsequent workers have failed to repeat his results. Ranvier [5] found that ligation of the femoral veins would not produce edema, but simultaneous ligation of the veins and division of the sciatic nerve produced this result. In 1879, Sotnitschewsky,[6] working in Cohnheim's laboratory, failed to produce edema by either of the methods mentioned, and found that by making the injections into the veins after ligation, fluid easily passed through collateral vessels. He found, however, that the injection of plaster of paris into the veins of the foot, with the application of a constrictor about the thigh until the plaster had set, produced massive edema of the extremity.

At the present time there is a growing tendency to ascribe the edemas of the extremities following thrombophlebitis to obstruction of the lymphatics.[7] Homans felt that the phenomena consequent on thrombophlebitis of the iliac vessels are incompatible with mere venous obstruction, and he recently reported experimental work that tends to show that the main lymphatic channels of the extremities, which run in close proximity to the iliac veins, are involved in the periphlebitic inflammation, and that it is the obstruction of these channels that is responsible for the postphlebitic edema.[8] In his experiments Homans found, as have many others, that simple ligation of the femoral or the iliac vein or both does not result in edema of the leg of the dog. The injection of bacterial emulsions, however, into an isolated segment of the external iliac vein produced an infectious thrombus and marked edema of the entire extremity. From his studies, Homans concluded that the cause of phlegmasia alba dolens is a lymphatic obstruction due to the inflammatory reaction around an area of thrombophlebitis, and that the basic lesion is always in the common or external iliac vein, however far it may extend peripherally.

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5. Quoted by Sotnitschewsky: Virchows Arch. f. path. Anat. **77**:85, 1879.

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METHODS OF EXPERIMENTATION AND RESULTS

We set out to repeat the experiments of Homans. The experiments were performed on the hind legs of dogs, the opposite limb in each animal being used for control. All operative procedures were carried out under ether anesthesia, with morphine premedication, and the usual aseptic precautions were observed. The experiments fall into a series of groups that led to the development of a simple, reliable method of producing edema comparable to that which follows human thrombophlebitis. Analysis was then made of the possible factors involved, so that the mechanism of the formation of edema and some of its characteristics could be determined.

Simple Ligation of the Iliac and Femoral Veins.—In the first group of animals the following veins were ligated: the common iliac vein on one side, the common and the internal iliac veins of the same side, both common iliac veins, both common plus both internal iliac veins, the femoral vein and the femoral plus the iliac veins of the same side. None of these measures produced noticeable edema of the leg. In many of the subsequent experiments, ligations of the veins of one or both sides were done in addition to other procedures, also without resulting in the development of edema. These results are in accord with those of Homans and others in laboratory animals, and are comparable to those reported in man when the surgical ligation of the main veins of the extremity have not resulted in edema or any other circulatory disturbance.

Chemical Phlebitis and Periphlebitis of the Iliac Veins— In another group of animals we sought to repeat the experiments of Homans. Instead of using emulsions of living bacteria, however, which might conceivably spread beyond the regions intended, we used chemical irritants similar to those in use in the obliteration of varicose veins. Fifty per cent solution of sodium salicylate, in amounts varying from 2 to 6 cc., and tincture of iodine, from 2 to 8 cc., were injected into isolated segments of the common and external iliac veins. In some experiments some of the solution was sprinkled along the outside of the vein. In all of the animals there was considerable periphlebitic reaction, even to necrosis of the perivenous tissues, with or without thrombosis in the isolated segment. In none of these animals was there edema of the leg.

Mechanical Extirpation of the Iliac Lymph Glands and Lymph-Bearing Tissues.—Having failed to produce edema of the leg by causing periphlebitic inflammation with presumable involvement of the adjacent principal lymph channels, we attempted to interrupt the lymphatic return

from the extremity by mechanically dissecting out the iliac lymph glands together with all of the retroperitoneal fatty and areolar tissues from the bifurcation of the aorta to Poupart's ligament, and from the posterior parietal peritoneum to the psoas muscles. The common and internal iliac veins were ligated and divided at the same time, only the artery being left intact. In some experiments even the adventitia of the artery was dissected off, to exclude any contained lymphatics. In the first animal operated on, marked edema of the entire thigh and leg developed. Dry gangrene of the leg subsequently ensued, because of a traumatic thrombosis of the artery and of the vein. Two other animals had slight, transient edema, in one of which extensive thrombosis of the veins extending down into the leg was found. In the remaining eight animals of this group, there were no traces of edema, although in several the dissection was repeated to remove any regenerated lymphatics and the collateral veins were ligated. The failure to produce edema in these experiments seemed to indicate that interruption of the lymph channels along the iliac vessels was not sufficient to produce edema of the corresponding limb; and while we could not be sure that all lymph vessels were removed by our operation, there was much more inflammation of the adjacent tissues as a consequence of the dissection than could be expected to result from an inflammatory process within the iliac veins.

Peripheral Injection of Irritants into Veins.—Our next attempt was to produce an extensive peripheral venous obstruction, by the injection of irritants peripherally, from the femoral veins. The vein into which the injection was to be made was exposed through a short incision just below Poupart's ligament and freed from its surrounding structures, and a ligature was placed just below the ligament. A needle was then tied into the vein, pointing downward and the injections made. Fifty and 70 per cent alcohol was used, in amounts of from 10 to 20 cc. In practically every one of these animals, marked edema ensued (fig. 1). The swelling developed during the first twenty-four hours, reached its maximum in from two to three days, then gradually subsided, and disappeared entirely in from two and one-half to three and one-half weeks. The edema appeared first and was most marked in the thigh, extending later to involve the entire leg and foot. In some of the animals it advanced also to the anterior abdominal wall, sometimes reaching as high as the xiphoid process. When most severe, the swelling was firm and brawny; when less marked, it was soft and pitting. At autopsy, extensive thrombosis or fibrous obliteration of the femoral veins was found, with marked perivenous infiltration. In some instances, there was actual necrosis and abscess formation.

These experiments indicated that the peripheral injections of chemical irritants into the main veins of the extremity resulted in edema of the limb, and suggested that the swelling was due to extensive peripheral block of the venous return. Two factors, however, still had not been ruled out, the perivenous inflammation that might affect the concomitant lymph channels and a possible direct effect of the irritant on the wall of the vessel, leading to increased permeability and exudation.

Production of Intravascular Thrombosis.—To avoid the criticisms indicated in the preceding paragraph, we sought for a bland, obturating agent that would occlude the vessels and not injure the wall of the vessel or the perivascular tissues. An emulsion of barium sulphate in

Fig. 1 (dog 35).—Edema of the leg twenty-four hours after the injection of 20 cc. of 50 per cent alcohol into the left femoral vein.

gelatin was injected into a series of five dogs. Edema of an extreme degree resulted in all of the animals. Three of the five died, and one seemed to have a great deal of pain on awakening, so the procedure was abandoned. Besides, the introduction of a metallic poison, to produce a bland intravascular thrombus, could be severely criticized.

Tissue extracts were then used for the peripheral injection, with the idea of producing bland noninflammatory thrombotic obstruction of the veins. The extracts were made of muscles of the hearts of dogs. Animals on which autopsies had been performed were used. The hearts were removed under aseptic care, minced and extracted with sterile distilled water or physiologic solution of sodium chloride. Injection of such extracts, in amounts from 15 to 30 cc., usually resulted in edema

of the leg, similar to that produced in the earlier experiments (fig. 2*A*). The edema was less uniform in degree than by the other methods, and was missed in a few experiments.

To pursue the idea a step further so as to produce edema by the injection of perfectly bland substances that would cause thrombosis but no perivascular inflammation, a series of animals was given injections of their own serum. Blood was drawn from the heart and allowed to clot, and the serum was reinjected, against the stream, into the femoral veins. In these animals also striking edema of the extremity developed (fig. 2*B*). Here, however, the edema was inconstant and of unequal intensity. The experiments to this point had convinced us that the

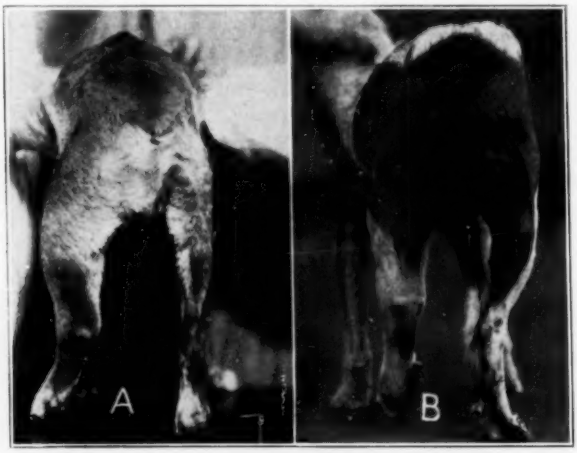

Fig. 2.—*A*, edema of the leg three days after the injection of 20 cc. of fresh heart muscle extract into the left femoral vein (dog 36). *B*, edema of the leg two days after the injection of 20 cc. of autogenous serum into the left femoral vein (dog 37).

obstruction of the veins of an extremity, with the use of the blandest possible substances, was followed by the development of edema in that limb. It was difficult to attribute any important rôle to the lymphatics in the mechanism of this edema.

Because of the inconvenience of preparing the extracts of muscles of the heart or the serum for further studies as to the nature and mechanism of the edema, the concentrated tissue extract prepared by C. A. Mills, and sold under the trade name fibrogen (Merrill), was used. Quantities of this preparation as small as from 0.5 to 1 cc. injected peripherally into the femoral vein resulted in extensive thrombosis of the veins and marked edema of the extremity (fig 3).

These edemas, like those following the injection of irritants, developed during the first twenty-four hours, and never lasted for more than from three and one-half to four and one-half weeks (table 1).

Postmortem Observations.—Animals were killed at various intervals after the injections, and the limbs were dissected. In general, the more extensive the edema, the more hemorrhagic the exudate proved to be. In limbs with marked swelling, the tissues were completely infiltrated with a hemorrhagic fluid. In the slight edemas, the fluid was thin and colorless. With the severe edemas there was also a heavy deposit of fibrin on the muscle bundles. The veins were thrombosed in all of

Fig. 3.—*A*, edema following the injection of 2 cc. of fibrogen into the left femoral vein. *B*, edema following the injection of 1 cc. of fibrogen into the right femoral vein.

TABLE 1.—*Circumference of Edematous Limbs (Twenty Hours After Injection of 1 cc. of Fibrogen into the Left Femoral Vein)*

	Dog 91		Dog 92	
	Right	Left	Right	Left
Foot	7.0 cm.	8.0 cm.	7.8 cm.	8.5 cm.
Leg	10.5 cm.	13.5 cm.	8.5 cm.	13.0 cm.
Thigh	23.0 cm.	28.0 cm.	18.5 cm.	26.5 cm.

the animals with edema (fig. 4), the extensiveness of the thrombosis usually corresponding to the severity of the edema. In the milder forms, the thrombosis reached only to the knee; in the severe ones, it extended

to the ankle. The tributaries of the veins were also occluded for a variable distance. The vein seemed to be somewhat more adherent to its surrounding structures in the occluded portions than elsewhere. In a few of the animals, the edema extended to the abdominal wall as high as the xiphoid process. Pulmonary embolism was seen occasionally (figs. 5, 6, 7 and 8).

Protein Content of the Edema Fluid.—It was thought that determinations of the protein content of the fluid might shed some light on the mechanism of the edema. Through the courtesy of Professor Farmer, of the department of chemistry, determinations of the protein content in a series of experiments have been made by the refractometric method (table 2). These determinations indicate a high protein content, the values ranging from 1.25 to 3.4 per cent. It is our impression, however, that the protein content is directly proportional to the severity and

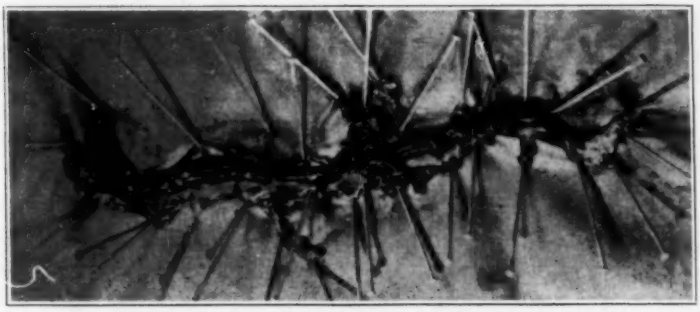

Fig. 4.—Vein dissected out and opened, showing intravascular clot.

TABLE 2.—*Protein Content of Edema Fluid* *

Dog	Duration of Edema	Protein Content, per Cent
48	24 hours	2.33
57	3 days	3.08
62	4 days	3.34
63	2 days	2.40
80	3 days	1.21
89	20 hours	2.64
90	20 hours	3.30
95	20 hours	2.24
96	20 hours	3.30

* The determinations were made with the refractometer by Miss Alice Reed, A.B., of the Department of Chemistry.

the duration of the edema. Further studies are now in progress concerning these changes in the chemical nature of the edema fluids.

Injections into the Saphenous Vein.—In a series of four animals, fibrogen was injected into the saphenous veins, in a retrograde direction, from a point close to their junctions with the femoral trunks. In two of

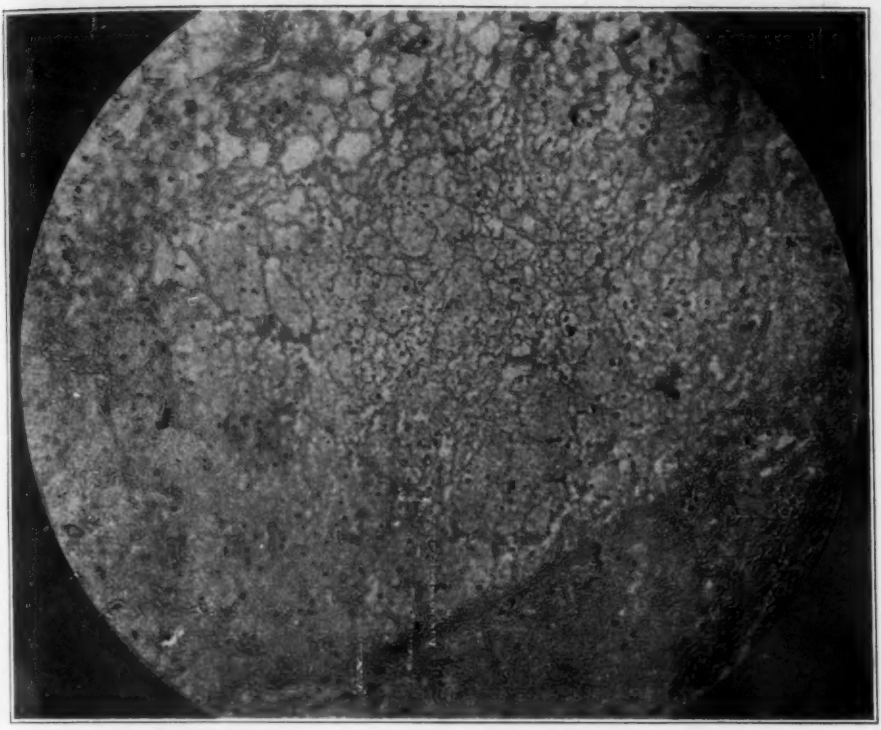

Fig. 5.—Photomicrograph of edematous tissue, showing fibrin strands and slight cellular infiltration.

Fig. 6.—Edematous tissue one week after injection, showing organization of exudate.

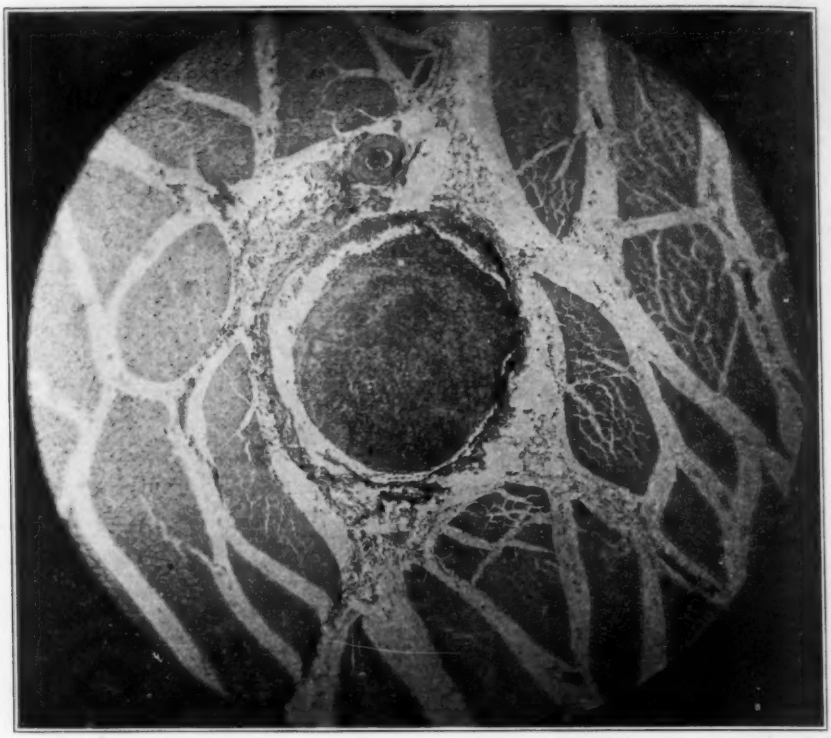

Fig. 7.—Low power section through the leg, showing occlusion of the vein and edema of the tissues. Note the absence of inflammatory reaction about the vein.

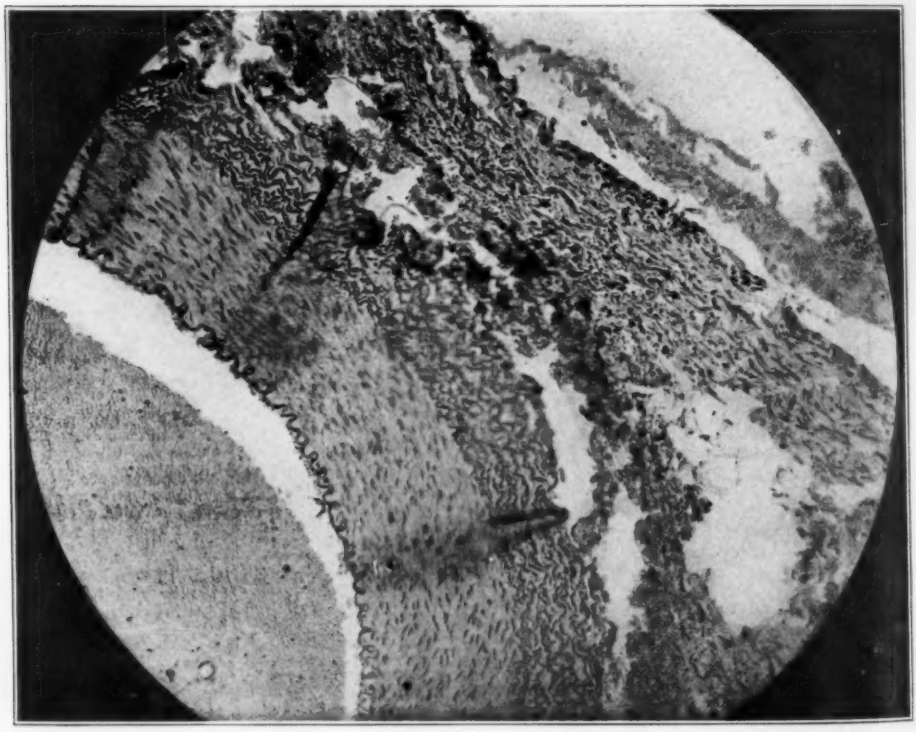

Fig. 8.—Adjacent portions of the femoral artery and vein. Note the normal structure of the artery and the absence of marked perivenous inflammatory reaction.

these experiments, the deep veins were intact. Following the injection, no edema or other circulatory disturbance resulted. In the other two animals, the femoral veins had previously been obliterated by the injection of coagulants. In both of these limbs there was an enormous edema following the obliteration of the saphenous veins. The significance of these few observations for the injection treatment of veins with occluded deep circulation is obvious.

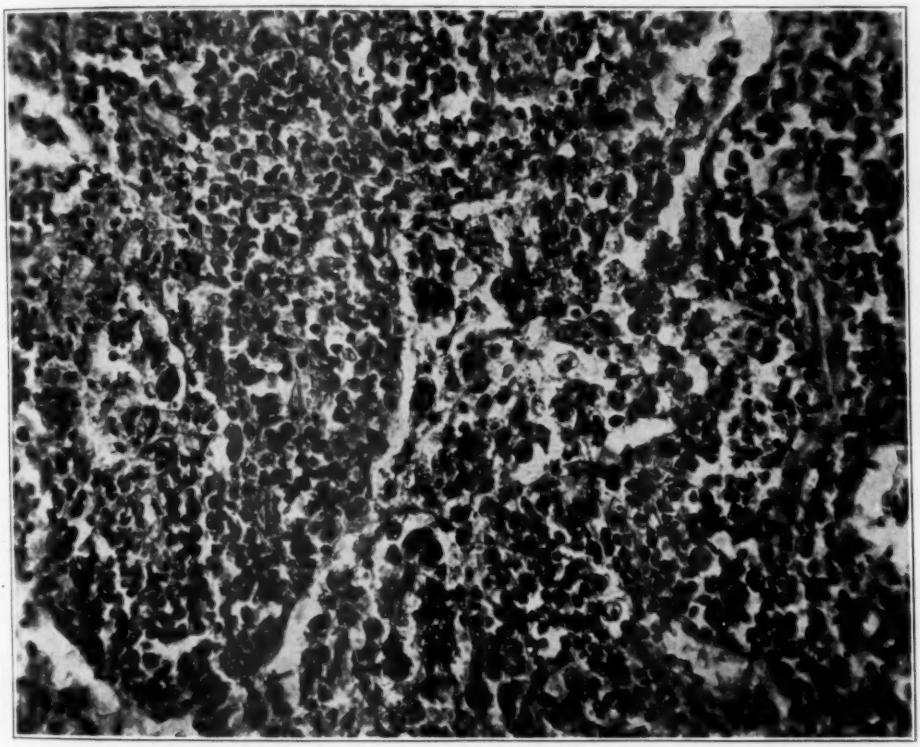

Fig. 9.—Iliac lymph node from an animal into whose foot india ink was injected at the height of edema. Note the fine black particles of ink within the cells, as well as in the lymph spaces.

Experiments with Heparin.—The question rose as to whether the injected substances themselves might not be sufficient to produce the edema, the venous thrombus being but an incidental factor. To rule out this factor, injections were made in the usual fashion, the fibrogen being diluted in a few cubic centimeters of sterile water. The same quantity of fibrogen, diluted with from 200 to 300 mg. of heparin and dissolved in a similar quantity of sterile water, was injected into control animals. In the experiments in which heparin was not used marked

edema resulted, and the veins were found to be extensively thrombosed. In those in which heparin was used, the thrombus was limited to the first 1 or 2 cm. of the vein, and there was no edema.

Injection into the Lymphatics.—In two animals with edema, 1 cc. of emulsion of india ink was injected into the footpads, and the animals were killed after two and one-half and sixteen hours. In the iliac lymph glands of neither of these animals could particles of ink be demonstrated. In control animals into which the same quantity of ink was injected at the same time and which were killed after the same intervals, pigmentation of the iliac glands was observed. India ink was injected into two other animals with marked edema of the legs, and the animals were killed after twenty-four hours. In both, ink was recovered in the iliac glands (fig. 9). In another series of four animals, the injections

TABLE 3.—*Summary of Experiments*

Type of Experiment	Number	Edema in
Ligation of veins alone	7	0
Ligation plus injection of irritants into iliac veins	6	0
Mechanical extirpation of lymphatics	12	3
Alcohol injected peripherally (femoral)	17	17
Injections of barium-gelatin emulsion	5	5
Injections of heart muscle extract	17	16
Injections of autogenous serum	10	8
Injections of fibrinogen	41	41
Heparin injected (plus fibrinogen or muscle extract)	6	2
Fibrinogen injected into saphenous vein	4	2
Total experiments	125	

of fibrogen into the femoral veins and the injections of ink into the foot were made simultaneously. The dogs were killed after twenty hours, and in three of the four there was definite discoloration of the iliac lymph glands. These experiments definitely proved that the lymphatics were permeable, even at the height of the edema. While it is true that the passage of the particles of ink was delayed in the limbs with edema, this is readily explained by the pressure exerted on the lymph vessels by the edema and by the limitation of activity in the edematous leg (table 3).

COMMENT

The experiments described have led to a simple, reliable method of producing edema in the extremity of the dog which is comparable to that seen in man following femoral or iliac thrombophlebitis. Simple ligation of the main veins of the extremity failed to result in such an edema. This, in view of the results of the production of an extensive peripheral obstruction of the veins, indicates that the simple ligation fails because the collateral supply is too readily developed to permit a

considerable degree of venous insufficiency. The production of a localized chemical phlebitis of the iliac veins, with more or less associated periphlebitis, also failed to result in edema of the extremity. The mechanical extirpation of the lymph-bearing tissues did not, in most of the experiments, lead to the development of edema of the corresponding limb. These results indicate that obstruction of the lymphatics does not play a primary rôle in the development of the postphlebitic edemas.

Obliteration or obstruction of the peripheral veins over a sufficiently extensive area in almost every instance was followed by the development of typical phlegmasia alba dolens. Such an obstruction by the injection of the blandest substances possible, even of the animal's own serum, provides little support for the theory of a lymphatic obstruction as the cause of the edema. Finally, the experiments with the injection of india ink definitely proved the patency of the lymphatics, even at the height of the edema. While it is true that the transport of particles of ink was delayed in the edematous limbs, this is readily explained by the pressure exerted on the lymphatics by the edema fluid. Furthermore, it is known that muscular activity is an important factor in furthering the flow in the lymphatics. These greatly swollen limbs are held immobile by the animals, depriving the lymph stream of the pumping action of the muscles.

The duration of the edema was directly proportional to its intensity. In none of the experiments, however, did it last for more than from three and one-half to four and one-half weeks. In this respect, the edemas differed from those of severe human cases of phlegmasia alba dolens in which the swelling may persist indefinitely, or may recur with excessive standing or walking. The transient nature of the edema in the animals is accounted for by several factors. As will be seen in the microscopic preparation (figs. 10 and 11), canalization of the thrombi occurs promptly, and probably results in some measure of restoration of the venous return. The rapid development of collateral circulation, as evidenced by the appearance of dilated superficial veins on the thigh and abdomen, and the enlargement of otherwise inconspicuous deep veins indicate the degree and rapidity of this collateral development. A final factor is seen in the difference in hydrostatic pressure in man as compared with the quadruped. This, plus the much earlier resumption of muscular activity on the part of the dog, probably further favors the early disappearance of the edema.

The rôle of lymphostasis in the thrombophlebitic edemas should not be denied. In the first place, venous obstruction per se increases the flow of lymph, and the rate of transport does not keep pace with the rate of production, as the mechanical pressure of the edema fluid and the immobilization of the edematous limb seriously interfere with the movement of lymph. In later stages of edema, the connective tissue

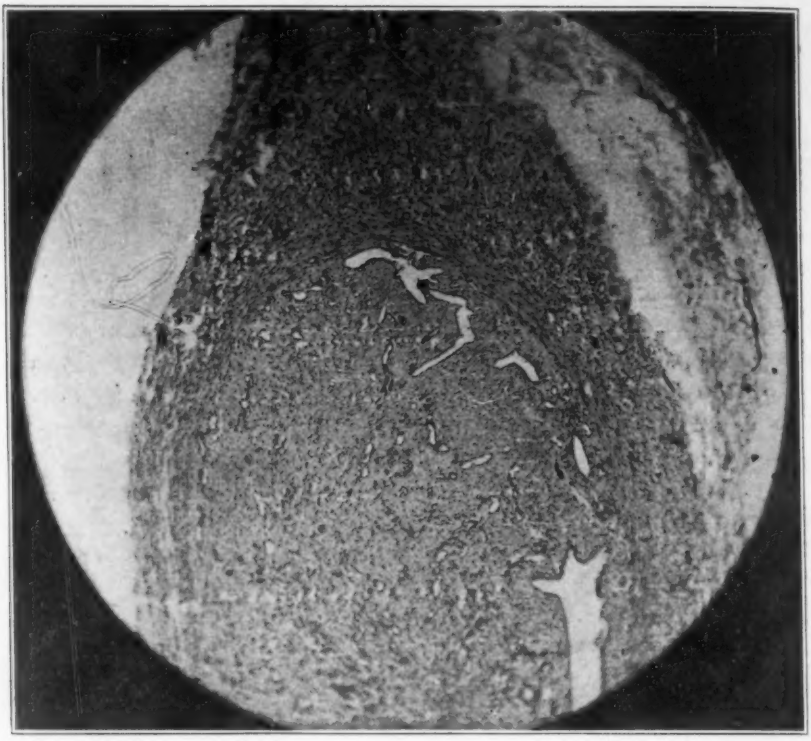

Fig. 10.—Low power photograph after one week, showing obliteration of the femoral vein, and active canalization of the thrombus.

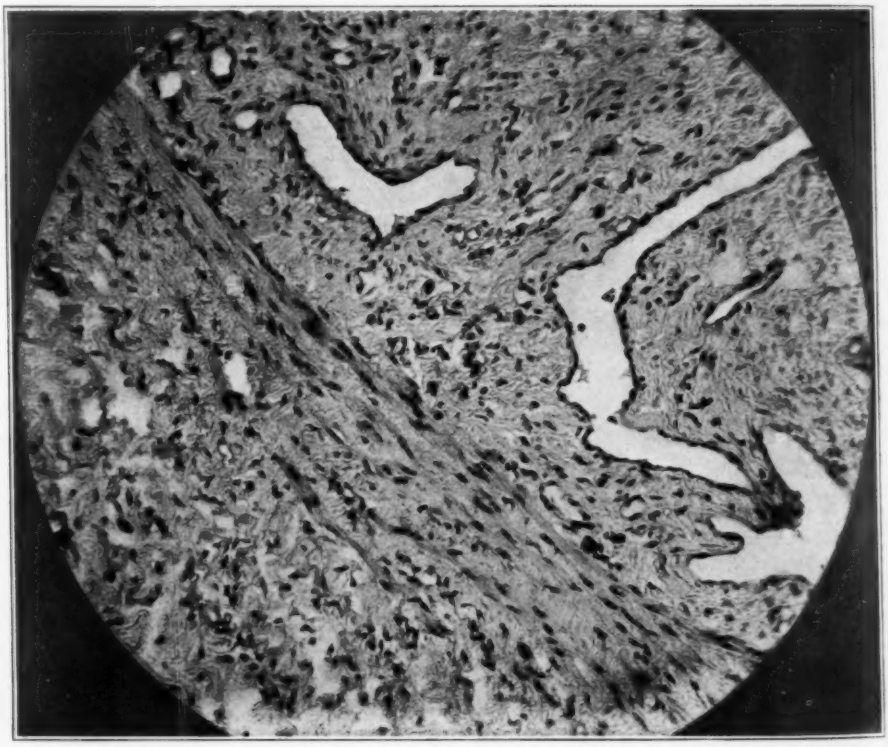

Fig. 11.—High power view of section in figure 9, showing canalization of the thrombus.

reaction, which is the result of the persistence of a protein-rich exudate in the tissues, will strangle the lymph channels and cause a peripheral lymph block. In tissues excised during Kondoleon operations one can uniformly observe such dilated lymphatics.

This secondary lymphostasis, however, has nothing in common with the lymphatic obstruction postulated by Homans and Zollinger, Reichert [9] and others, who claim a primary obstruction of the perivenous lymph channels and lymph glands in thrombophlebitic edema. Our results fail to confirm their supposition. We are aware of the fact that the chronic edema seen after iliac thrombosis in man presents additional factors that we have not reproduced in the animal, namely, the superimposed infections of the skin, the recurrent attacks of erysipelas with more burden on the lymphatics and the thrombophlebitic ulcers. Also the so-called "idiopathic" edema, without any evidence of venous thrombosis, may have a type of mechanism that is different from the one reproduced here. The extensive venous thrombosis, however, which not only blocks the femoral or iliac veins at one segment, but extends far into the tributaries, closely imitates the condition encountered in deep venous thrombosis in man.

The accumulation of fluid in the tissues cannot be explained purely on the basis of a filtration edema. It is true that when capillary pressure rises above the osmotic pressure of the blood, the flow of fluid from the tissues to the capillaries is reversed. Obviously, there is a great rise in capillary pressure following mechanical obstruction in the veins. The edema, however, which can be observed in normal subjects standing erect and immovable for thirty minutes contains only a small amount of protein; the endothelium is intact and hardly or not at all permeable.[10] The fact that our edema fluids contain high percentages of protein can be interpreted only as a sign of endothelial damage, resulting in increased permeability to the proteins of the blood. The capillary stasis, which deprives the capillary endothelium of sufficient oxygen, is the most probable cause for this leakage of protein. The work of Landis has conclusively shown the great sensitivity of endothelium to even a small diminution of the supply of oxygen.[11]

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That the edema fluid is rich in protein explains certain characteristics of thrombophlebitic edema. In the first place, it explains why the edema does not disappear as fast as a simple filtration edema, owing to an increase in venous pressure. As long as the increased capillary permeability persists, the exudation of protein-containing fluid will go on. However, when the capillary permeability is restored, it will also become impermeable to the protein in the exudate.[12] The osmotic pressure of this exudate seems also of importance and is now being investigated.

Edema fluids containing protein can be absorbed through the lymphatics, and the experiments of Lewis[13] showed conclusively that protein is transported along this route. Another mechanism has been pointed out by Landsberg,[14] who observed that protein may be broken down by enzymes produced, no doubt, in adjoining cells. The cleavage products can then be directly absorbed into the blood stream. This might explain the death of some of the experimental animals and the toxic, febrile reactions that occur in acute thrombosis without infection in man.

The hemorrhagic, protein-rich exudate is not indifferent to the tissues. The connective tissue reaction will result in fibrosis and further inhibition of venous and lymphatic transport. We gained the impression in our experiments on animals, that the degree and duration of the edema were related to the height of the protein content and the hemorrhagic character of the fluid. From a clinical standpoint, much will depend on whether the edema can be made to subside rapidly and whether or not the capillary damage is permanent.

The Kondoleon operation, which we practice according to the modification of Sistrunk,[15] may be interpreted in the light of our experiments to act by removing a large amount of diseased, fibrous connective tissue with vacuolar spaces that retain water easily. The removal of the fascia might expose the subcutaneous tissues to a more direct muscular pump action. The working hypothesis that new lymphatic connections drain off the lymphostasis is not tenable, because even if lymphatic block were a primary factor, the iliac lymph glands and channels, which drain the lymphatics of the entire lower extremities, would not be affected by this operation.

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SUMMARY

1. Ligation of the iliac and femoral veins, alone or in all possible combinations with the contralateral veins, did not produce edema in the lower extremities of dogs.

2. A localized chemical phlebitis and periphlebitis induced with strong irritants, such as 50 per cent sodium salicylate and tincture of iodine, produced a segmental thrombosis but no edema of the limb.

3. Removal of the iliac lymph glands together with all of the retroperitoneal fatty and areolar tissues from the bifurcation of the aorta to Poupart's ligament failed to produce edema of the limb even when the common and internal iliac veins were divided at the same time. In several animals the dissection was repeated to remove any regenerated lymphatics and the collateral veins were ligated, but edema did not develop.

4. From 50 to 70 per cent alcohol injected peripherally into the femoral vein caused extensive venous thrombosis extending into the tributaries and a marked edema lasting from two and a half to three and a half weeks.

An emulsion of barium sulphate in gelatin also produced marked edema.

Tissue extracts from muscles of the hearts of dogs, the dogs' own serums and finally a concentrated tissue extract, fibrogen, when injected into the femoral vein, caused an extensive venous thrombosis with marked edema. The edema fluid was hemorrhagic and contained comparatively high percentages of protein, indicating a damage to the capillary endothelium. If the fibrogen was prevented from forming a clot by the simultaneous injection of heparin, there was no edema.

5. In spite of marked edema, particles of india ink, injected into the foot reached the iliac lymph glands, although delayed by the pressure of the fluid and by the limitation of muscular activity.

6. An obstruction of the peripheral veins over a sufficiently extensive area with a bland, noninflammatory clot produced marked edema, with very little and only secondary involvement of the lymphatics. These results do not confirm the results of recent workers, who emphasize lymphatic obstruction.

7. Some clinical applications of these observations are pointed out.

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THE IMMEDIATE CONTRACTION OF CUTANEOUS GRAFTS AND ITS CAUSE*

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We have often noticed that there is a definite shrinkage in the size of free skin grafts immediately after being cut; this fact has also been recorded in the literature by other observers, but so far as we have been able to ascertain, no one has attempted to measure the exact amount of shrinkage or to compare this shrinkage in the different types of grafts. This report is the result of an investigation to determine the amount of contracture and to explain the probable cause.

In cutting grafts of different thicknesses we found that the shrinkage seemed to vary with the depth at which they were cut. For this reason we selected for measurement areas of skin of different thicknesses: whole thickness, half thickness, thick Ollier-Thiersch and thin or true Ollier-Thiersch grafts.

The whole thickness grafts included the whole thickness of the skin, excluding the hypoderm. The half thickness grafts were cut about half through the corium. The thick Ollier-Thiersch grafts were cut with the aid of Blair's suction boxes and included the papillae of the corium. The true Ollier-Thiersch grafts, which are the thinnest that can be cut, were also obtained with the aid of Blair's suction boxes and included the epidermis and the tips of the papillae of the corium (fig. 1).

HISTOLOGIC ANATOMY

The skin consists of three layers: epidermis, dermis or corium, and the hypodermis or subcutaneous layer. The epidermis is a nonvascular covering composed of pavement epithelial cells. The dermis or corium is made up of dense fibrous tissue with strands of yellow elastic tissue. It contains the blood vessels, lymphatics, nerves, touch follicles and hair follicles and some of the oil and sweat glands. The hypodermis consists of bundles of loose connective tissue containing masses of fat cells in their meshes. Most of the sweat glands and the deep hair follicles also lie in this layer.

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The epidermis is divided into four layers of cells: the stratum corneum, stratum lucidum, stratum granulosum and stratum mucosum (fig. 1).

The stratum corneum consists of several layers of flattened non-nucleated cells, the more superficial of which assume the form of horny

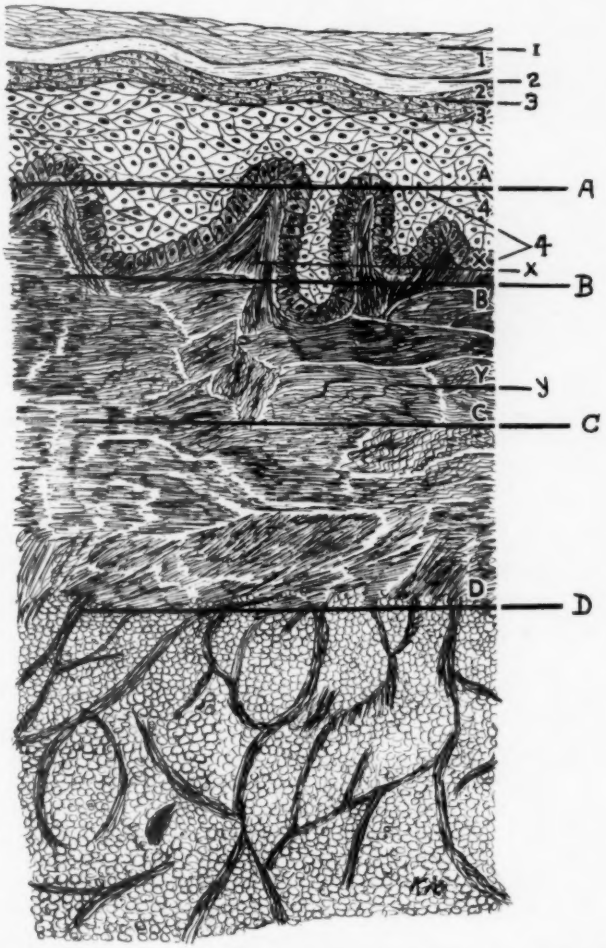

Fig. 1.—Schematic drawing of a vertical section of the skin. *1* indicates the stratum corneum; *2*, stratum lucidum; *3*, stratum granulosum; *4*, stratum mucosum; *A*, level at which the true Ollier-Thiersch grafts were cut; *B*, level at which the thick Ollier-Thiersch grafts were cut; *C*, level at which the half thickness grafts were cut; *D*, level at which the whole thickness grafts were cut; *X*, papillary layer of the corium; *Y*, reticular layer of the corium.

scales, which are gradually removed by friction. The stratum lucidum consists of an apparently homogeneous layer of flattened cells which con-

tain granules of keratohyalin. The stratum granulosum consists of three or four layers of flattened cells around the nuclei of which are granules of eleidin, a substance that apparently represents an intermediate stage between the protoplasm of the deeper cells and the keratin of the superficial layers. The stratum mucosum consists of several parts: a basal layer or the stratum germinativum, consisting of one or two layers of cylindrical cells with large nuclei, standing on a basement membrane, and above these cells several layers of prickle cells united to each other by filamentous processes.

The corium is divided into two parts: the pars papillaris or papillary layer and the pars reticularis or reticular layer.

The papillary layer, which consists of fine fibrous tissue with some elastic tissue, is thrown into ridges that are covered by the overlying mucous layer of the epidermis. These folds are called papillae. They afford favorable positions for the lodgment of the terminal capillaries and special organs of touch. The papillae are best developed on the flexor surfaces of the hands and feet, and they do not vary throughout life.

The reticular layer is a continuation of the papillary layer. In this layer the fibrous and elastic tissue is more closely interlaced, and it is the "leather" of the skin.

The general course of the fibrous bundles within the corium is parallel or oblique to the surface. Some strands come upward vertically from the subcutaneous layer below, traverse the reticular layer and either bend over the fibrous bundles in this layer and go down again or join these bundles. The bundles that are best developed have a direction parallel with the usual lines of tension of the skin; hence wounds of the skin that are at right angles to these lines tend to gape most. The bundles take a direction nearly at right angles to the long axis of the limbs; they run obliquely on the trunk and caudally and laterally from the spine. Their direction on the face and neck can best be seen in the illustration (fig. 2). The lines of tension of the skin are called the lines of Langer.

The elastic tissue, which constitutes a considerable portion of the corium, occurs as fibers and networks (fig. 3). In the reticular stratum they form strong bundles, corresponding with the general arrangement of the fibrous tracts. Toward the surface of the corium, the elastic fibers become finer and more branched and anastomose beneath the epidermis, forming a fine subepithelial elastic network.

These elastic fibers unquestionably determine the shrinkage of cutaneous grafts after the grafts have been cut, and this shrinkage will depend on the depth at which they were cut. If the whole thickness of the skin is taken, the shrinkage will be maximum, whereas if only the

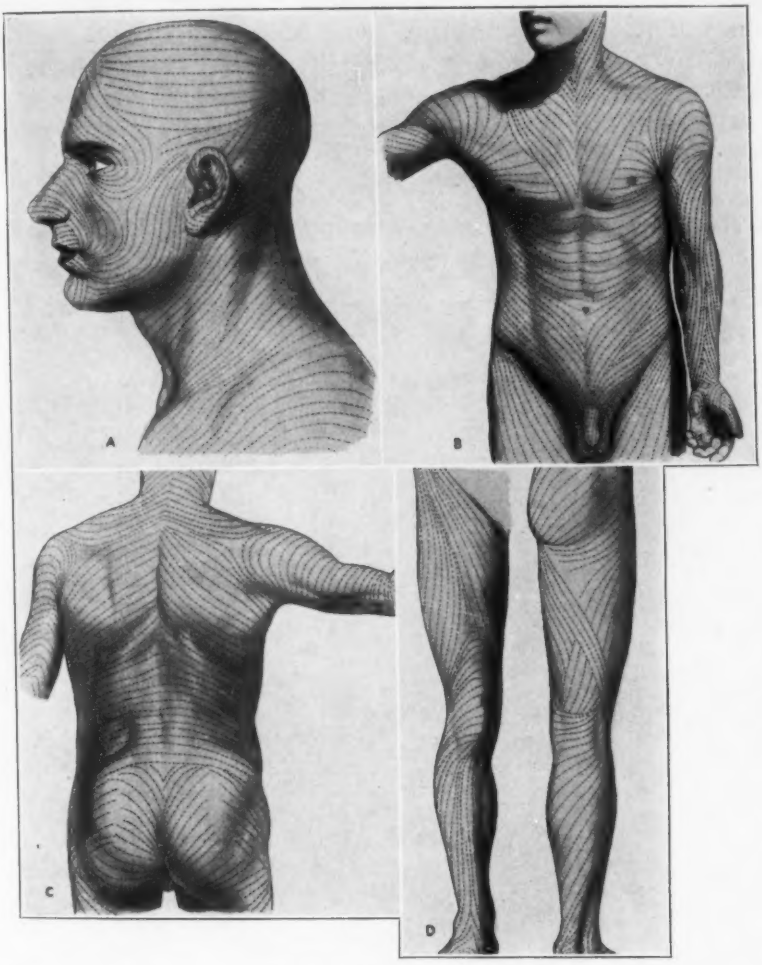

Fig. 2.—These illustrations, *A*, *B*, *C* and *D*, show the lines of normal tension of the skin known as the lines of Langer. Incisions through the skin across these lines will gape wider than those cut parallel to them, and incisions closed parallel to these lines will be less likely to cause wide scars than those closed across them. The elastic tissue of the corium throws the papillary layer into definite folds which cause these patterns. The epithelium plays no part in the formation of these folds, as it merely covers the corium beneath. These patterns are practically uniform, with only minor individual variations. This illustration is redrawn from Kirschner and Schubert (Allgemeine und spezielle chirurgische Operationslehre, Berlin, Julius Springer, 1927, vol. 1, p. 326). *A* shows Langer's lines of normal skin tension on the head and neck; *B*, Langer's lines of normal skin tension on the front of the trunk and upper extremity; *C*, Langer's lines of normal skin tension of the back of the trunk and buttocks; *D*, Langer's lines of normal skin tension on the front and back of the thigh and leg.

epidermis and the papillary layer are taken, as in a deep Ollier-Thiersch graft, then the shrinkage will be much less. A graft that does not include any of the corium, or only the tips of the papillae and the epidermis, should have no shrinkage, except the slight amount due to the natural contraction of the cells themselves.

TECHNIC

The following procedures were used in measuring the grafts before and after cutting:

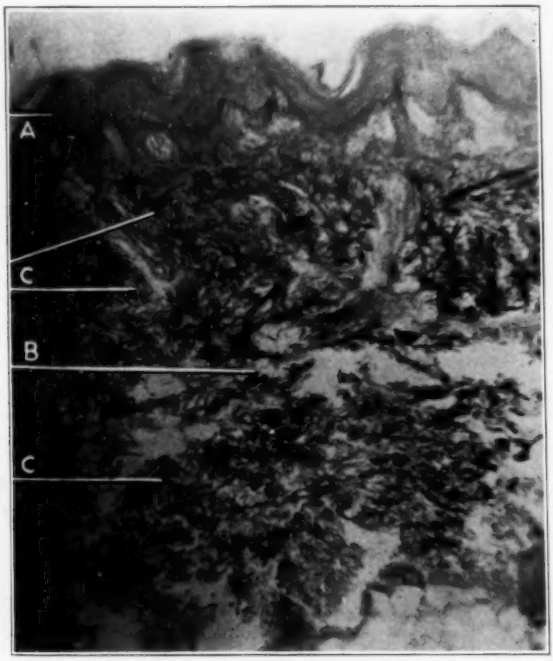

Fig. 3.—Photomicrograph of a section of a whole thickness graft stained with Weigert's stain to bring out the elastic fibers of the corium. No counter-stain. *A* indicates epithelium; *B*, corium; *C*, elastic fibers which take a very deep stain.

Sterilized perforated cellosilk and 5 per cent brilliant green in alcohol are the materials used in securing the measurements. Where whole thickness and half thickness grafts are to be measured, the size of the graft desired is carefully outlined on the cellosilk with the brilliant green applied with the point of a toothpick. This outline, which is the exact size of the graft desired and also of the graft before cutting, is placed on the area from which the graft is to be taken and reoutlined with brilliant green; the dye passing through the perforations in the cellosilk leaves a dotted pattern on the skin. These dots are then connected, and the outline is thus marked on the skin. The graft is then removed and flattened

out on another piece of cellosilk, care being taken not to stretch it. A second tracing is then made, which gives the area of the graft after shrinkage has taken place.

A different procedure had to be used in obtaining the measurement of the shrinkage in thick and true Ollier-Thiersch grafts, because the margins of these grafts could not be accurately cut in a given pattern, and because the thick Ollier-Thiersch grafts always tapered into true Ollier-Thiersch grafts at the edges. In order to overcome this difficulty, a square with sides about 2.5 cm. long is made on the cellosilk and transferred to the skin in the center of the area from which the graft is to be cut. After cutting, the thick or the true Ollier-Thiersch graft is carefully spread on a board covered with protective tissue. The area previously marked out is then traced on a second piece of cellosilk, which gives the size of the square after shrinkage has taken place.

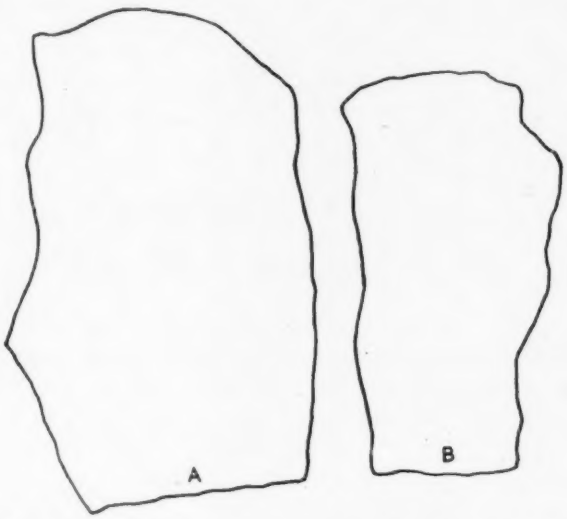

Fig. 4.—Outlines of a whole thickness graft taken from the abdominal wall of a man, aged 40 (table 1, case 15), who had a roentgen ray burn of the skin over the knee, which was excised and skin-graft applied. *A* shows the tracing made before cutting the graft; area, 29.0982 sq. cm. *B* shows the tracing made after cutting the graft; area, 16.4084 sq. cm. There was a shrinkage of 12.6898 sq. cm., or 43.61 per cent. Note the same general outline, which is much smaller in *B* because of the immediate shrinkage. (The original outlines have been reduced one half).

The tracings are then transferred to sheets of paper and the areas computed by means of a planimeter. The difference in the areas of each pair of tracings shows the shrinkage for that particular graft. As all the grafts are of different sizes, we used the percentage of shrinkage as a method of comparison (figs. 4, 5, 6 and 7).

The following tables were compiled from tracings secured by the procedure described. All of the grafts measured were obtained and transplanted by us in the course of routine work. The planimeter readings and the computations were made by one of us in order to make them as uniform as possible.

Fig. 5.—Outlines of a half thickness graft taken from the abdominal wall of a girl, aged 10 (table 2, case 2) who had a contracted scar from a burn which was released and grafted. *A* shows tracing before cutting; area, 6.5430 sq. cm. *B* shows tracing after cutting; area, 5.0323 sq. cm. There was a shrinkage of 1.5107 sq. cm., or 23.09 per cent. Note that the general outline is about the same and that the shrinkage is less than in the whole thickness grafts. (The original outlines have been reduced one-half.)

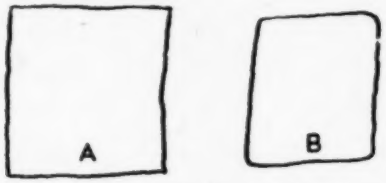

Fig. 6.—Outlines of a thick Ollier-Thiersch graft taken from the thigh of a man, aged 38 (table 3, case 13) who had a roentgen ray burn of the cheek, which was excised and skin-graft applied. *A* shows tracing made on the skin in the central part of the area taken in the graft; area, 4.3210 sq. cm. *B* shows tracing of *A* after the graft was cut; area, 3.7430 sq. cm. There was a shrinkage of 0.5/80 sq. cm., or 13.60 per cent. (The original outlines have been reduced one fourth of an inch.)

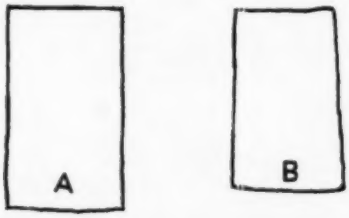

Fig. 7.—Outlines of a true Ollier-Thiersch graft taken from the thigh of a boy, aged 16 (table 4, case 8) who had granulating areas on both ears due to a burn. *A* shows tracing before cutting graft; area, 2.5411 sq. cm.; *B*, tracing after cutting graft; area, 2.5096 sq. cm. There was a shrinkage of 0.0315 sq. cm., or 1.23 per cent.

RESULTS OBTAINED WITH THE VARIOUS TYPES OF GRAFTS

Whole Thickness Grafts.—In this series of twenty there were twelve males and eight females. The variation in age was from 3 to 50 years. Nine grafts were taken from the abdominal wall; seven from the thigh,

and four from the arm. The area of the largest graft before cutting was 30.6425 sq. cm. and the largest area after cutting was 17.2288 sq. cm. The area of the smallest graft was 1.6256 sq. cm. before cutting and 0.9144 sq. cm. after cutting. The largest amount of shrinkage was 44 per cent and the smallest 43.01 per cent, with an average shrinkage of

TABLE 1.—*Whole Thickness Grafts*

Number	Sex	Age	Source of Graft	Area of Tracing, Sq. Cm.	Area of Free Graft, Sq. Cm.	Amount of Shrinkage, Sq. Cm.	Percentage of Shrinkage
1	Female	5	Abdominal wall	5.9900	3.9370	3.0530	43.67
2	Male	3	Abdominal wall	4.5110	2.5349	1.9761	43.86
3	Male	30	Abdominal wall	28.5699	16.0528	12.5171	43.80
4	Female	10	Abdominal wall	21.9862	12.3952	9.5910	43.63
5	Female	10	Thigh	14.9733	8.5344	6.4389	43.74
6	Female	46	Abdominal wall	10.3632	5.9050	4.4582	43.01
7	Female	6	Thigh	11.7856	6.6522	5.1334	43.56
8	Female	18	Arm	2.0320	1.1379	0.8940	44.00
9	Male	38	Thigh	2.6416	1.4935	1.1480	43.47
10	Male	26	Abdominal wall	14.2240	7.9781	6.2458	43.91
11	Male	50	Thigh	30.6425	17.2288	13.4137	43.78
12	Female	32	Thigh	3.5763	2.0370	1.5392	43.04
13	Male	24	Arm	3.1496	1.7780	1.3716	43.54
14	Male	37	Thigh	2.0726	1.1785	0.8940	43.13
15	Male	40	Abdominal wall	29.0982	16.4084	12.6898	43.61
16	Male	3	Abdominal wall	1.6256	0.9144	0.7112	43.75
17	Male	42	Abdominal wall	28.0822	15.7556	12.3266	43.89
18	Male	7	Thigh	1.6662	0.9372	0.7289	43.75
19	Female	22	Arm	6.2763	3.5585	2.7178	43.30
20	Male	18	Arm	3.3070	1.8643	1.4427	43.62

Average amount of shrinkage, 43.60 per cent.

TABLE 2.—*Half Thickness Grafts*

Number	Sex	Age	Source of Graft	Area in Tracing, Sq. Cm.	Area in Free Graft, Sq. Cm.	Amount of Shrinkage, Sq. Cm.	Percentage of Shrinkage
1	Male	12	Thigh	3.6472	2.7354	0.9118	25.00
2	Female	10	Abdominal wall	6.5430	5.0323	1.5107	23.09
3	Male	19	Arm	2.3241	1.7433	0.5808	24.99
4	Female	21	Thigh	4.9479	3.7364	1.2115	24.48
5	Male	30	Arm	2.0144	1.5146	0.4998	24.81
6	Female	21	Arm	2.5968	1.9878	0.6090	23.45
7	Female	21	Thigh	2.1513	1.5918	0.5595	26.00
8	Male	34	Abdominal wall	6.2445	4.6052	1.6393	25.70
9	Male	10	Thigh	2.6299	2.0092	0.6207	23.60
10	Female	21	Thigh	3.9870	2.9735	1.0135	25.42
11	Female	24	Arm	1.2189	0.9177	0.3012	24.71
12	Male	12	Thigh	5.2508	3.9156	1.3352	25.42
13	Female	45	Thigh	1.2245	0.9409	0.2836	23.17
14	Female	24	Arm	2.1716	1.6380	0.5336	24.57
15	Male	15	Abdominal wall	2.8072	2.0871	0.7201	25.65
16	Male	43	Thigh	3.7411	2.7901	0.9510	25.42
17	Female	30	Thigh	1.6723	1.2720	0.4003	23.93
18	Male	29	Arm	2.4191	1.8017	0.6174	25.52
19	Female	45	Thigh	1.8691	1.3820	0.4871	26.06
20	Male	32	Arm	1.6700	1.2389	0.4311	25.81

Average amount of shrinkage, 24.84 per cent.

43.60 per cent. The average amount of shrinkage in the grafts taken from the abdominal wall was 43.70 per cent; from the thigh, 43.49 per cent, and from the arm, 43.61 per cent. According to our findings therefore, a whole thickness graft shrinks a little less than half immediately after it is cut.

Half Thickness Grafts.—In this series of twenty there were ten males and ten females. The ages ranged from 3 to 45 years. Ten, or

half of the grafts were taken from the thigh; three from the abdominal wall, and seven from the inner side of the arm. The area of the largest graft was 6.5430 sq. cm. before cutting and 5.0323 sq. cm. after cutting. The area of the smallest graft was 1.2189 sq. cm. before cutting and 0.9177 after cutting. The largest amount of shrinkage was 26.6 per cent and the smallest, 23.09 per cent, with an average of 24.84 per cent. The average amount of shrinkage for the grafts removed from the abdominal wall was 24.81 per cent; from the thigh 24.85 per cent, and from the arm 24.83 per cent. It was impossible to cut the grafts at a uniform depth, which probably accounts for some of the shrinkage. Half thickness grafts have an immediate shrinkage of about one-fourth after being cut.

TABLE 3.—*Thick Ollier-Thiersch Grafts*

Number	Sex	Age	Source of Graft	Area in Tracing, Sq. Cm.	Area in Free Graft, Sq. Cm.	Amount of Shrinkage, Sq. Cm.	Percentage of Shrinkage
1	Male	10	Thigh	3.9194	3.5077	0.4117	10.51
2	Male	21	Thigh	2.7625	2.4476	0.3150	11.38
3	Female	15	Thigh	3.3995	3.1351	0.2644	7.77
4	Female	8	Thigh	4.2463	3.5989	0.6474	15.24
5	Female	17	Thigh	3.2771	2.9193	0.3578	10.91
6	Male	29	Abdominal wall	4.3606	3.8834	0.4772	10.94
7	Male	24	Abdominal wall	3.5194	3.1264	0.3930	11.16
8	Male	21	Thigh	3.9197	3.4137	0.5060	12.90
9	Female	17	Thigh	2.0546	1.8192	0.2354	11.45
10	Female	36	Thigh	3.0604	2.7117	0.3487	13.72
11	Female	30	Thigh	3.7909	3.1686	0.6223	16.41
12	Female	17	Thigh	3.5447	3.1414	0.4033	11.37
13	Male	38	Thigh	4.3210	3.7430	0.5780	13.60
14	Female	36	Thigh	2.8336	2.6098	0.2238	11.48
15	Male	24	Abdominal wall	3.4949	3.0995	0.3954	10.80
16	Female	17	Thigh	2.2289	1.9610	0.2679	12.01
17	Male	52	Thigh	3.1046	2.8488	0.2558	8.23
18	Male	29	Abdominal wall	3.5648	3.1341	0.4307	12.09
19	Female	19	Thigh	3.7566	3.2857	0.4709	12.53
20	Female	17	Thigh	2.5913	2.2874	0.3039	11.72

Average amount of shrinkage, 11.81 per cent.

Thick Ollier-Thiersch Grafts.—In this series of twenty there were nine males and eleven females. The variation in age was from 8 to 52 years. Four grafts were taken from the abdominal wall and the remainder, or 16, from the thigh. The area of the largest graft was 4.3606 sq. cm. before cutting and 3.8834 sq. cm. after cutting. The area of the smallest graft before cutting was 2.0546 sq. cm. and 1.8192 sq. cm. after cutting. The largest amount of shrinkage was 16.41 per cent and the smallest 7.77 per cent. There is a greater variation here than in the other types of grafts. This, we think, is due to the method of cutting, which precludes the possibility of securing grafts of absolutely uniform thickness. If case 2 and case 6 were not considered, the difference would not be so great, and the average for the series would be 12.23 per cent instead of 11.81 per cent, with the majority of the cases falling between 10 and 13 per cent. The average amount of shrinkage for the grafts removed from the abdominal wall was 11.26 per cent and from the thigh, 11.95 per cent.

True Ollier-Thiersch Grafts.—In this series of twenty there were eight females and twelve males. The variation in age was from 8 to 51 years. Three grafts were taken from the abdominal wall and the remaining seventeen from the thigh. The area of the largest graft before cutting was 3.0556 sq. cm. and 3.0353 sq. cm. after cutting. The area of the smallest graft was 1.0160 sq. cm. before cutting and 1.007 sq. cm. after cutting. The largest amount of shrinkage was 2.00 per cent, and the smallest was 0.51 per cent, with an average of 1.24 per cent. The average amount of shrinkage in the grafts taken from the abdominal wall was 1.08 per cent and in those taken from the thigh, 1.27 per cent. This shrinkage is due partly, perhaps, to a normal contracture of the

TABLE 4.—*True Ollier-Thiersch Grafts*

Number	Sex	Age	Source of Graft	Area in Tracing, Sq. Cm.	Area in Free Graft, Sq. Cm.	Amount of Shrinkage, Sq. Cm.	Percentage of Shrinkage
1	Female	20	Thigh	1.9753	1.7640	0.2113	1.06
2	Female	18	Thigh	1.7881	1.7576	0.0305	1.70
3	Male	30	Abdominal wall	2.4460	2.4333	0.0127	0.51
4	Female	10	Thigh	2.1207	2.0955	0.0152	0.72
5	Male	51	Thigh	2.9667	2.9184	0.0482	1.62
6	Female	20	Thigh	1.6908	1.4457	0.2451	1.45
7	Male	30	Abdominal wall	2.2326	2.1971	0.0355	1.59
8	Male	16	Thigh	2.5411	2.5096	0.0315	1.23
9	Female	21	Abdominal wall	2.4079	2.3799	0.0279	1.16
10	Male	10	Thigh	1.0160	1.0007	0.0153	1.50
11	Male	51	Thigh	2.5542	2.5034	0.0508	1.11
12	Female	10	Thigh	1.9050	1.8669	0.0381	2.00
13	Male	26	Thigh	2.1543	2.1023	0.2520	1.16
14	Male	14	Thigh	2.5679	2.5501	0.0177	0.69
15	Male	24	Thigh	1.8288	1.8103	0.0185	1.01
16	Female	8	Thigh	3.0556	3.0353	0.0203	0.66
17	Male	26	Thigh	1.6687	1.6357	0.0330	1.98
18	Male	10	Thigh	1.4630	1.4351	0.0431	1.73
19	Male	16	Thigh	2.3476	2.2193	0.2183	0.92
20	Female	18	Thigh	1.7475	1.5448	0.2027	1.16

Average amount of shrinkage, 1.24 per cent.

cells, but principally to errors made in copying the tracings. Theoretically, there should be no measurable shrinkage in these grafts since there is little or no elastic tissue in them, and the contraction of the cells would be very slight. Therefore, the whole shrinkage could be considered as an error in manipulation.

COMMENT

Whole thickness grafts, which shrink most, contain all the elastic tissue, with the exception of a few bundles that dip down into the hypoderm. Half thickness grafts, cut through the reticular layer of the corium, contain less elastic tissue, since we attempted to leave about half of the corium, and consequently they shrink less. Thick Ollier-Thiersch grafts, which included the papillae of the corium and which therefore

contained only fine elastic tissue in a looser network than the reticular layer below, shrink still less. True Ollier-Thiersch grafts, which include the epidermis and only the tips of the papillae of the corium, contain little or no elastic tissue and practically do not shrink as compared with the other types of grafts. From these observations, we feel justified in assuming that the elastic tissue in the fibrous bundles is the cause of the shrinkage.

Sections were stained with Weigert's stain, which is a stain for elastic tissue only, and these sections clearly indicated the varying

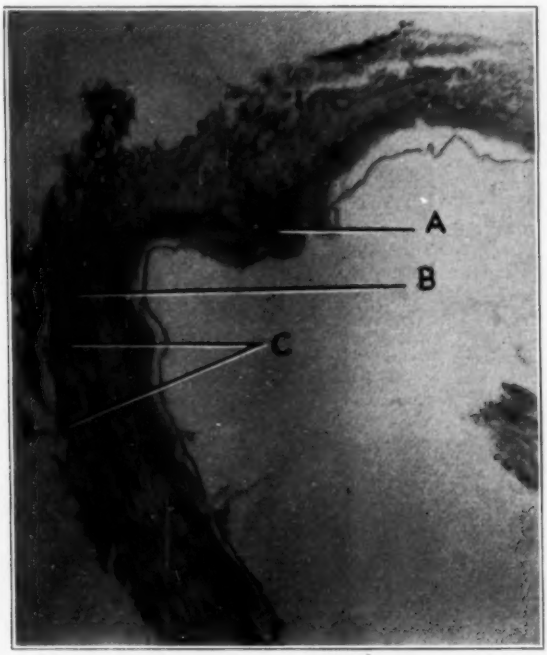

Fig. 8.—Photomicrograph of a section of a half thickness graft stained with Weigert's stain to bring out the elastic tissue. *A* indicates epithelium; *B*, corium; *C*, elastic fibers.

amounts of elastic tissue in the different grafts (figs. 3, 8 and 9). The sections of the true Ollier-Thiersch grafts did not show elastic tissue.

Age apparently plays no part in the amount of shrinkage of the grafts. Our series included patients whose ages ranged from 3 to 52 years, and there was no definite difference in the results.

The grafts were irregular in shape in order to fill the various defects for which they were cut, and so they could not be taken in the lines of normal tension of the skin. However, the shrinkage appeared to be the same in all directions, as after cutting the grafts retained the shape of the original patterns to a large extent. Furthermore, the shrinkage appears to be about the same in grafts taken from different parts of the

body. Grafts from the arm were taken from the upper inner side of the arm. Grafts from the abdominal wall were usually taken from the lower right or left quadrants, and the grafts from the thigh were usually taken from the upper half of the anterior portion.

CONCLUSIONS

The only variable factor in these grafts is the amount of corium with its elastic tissue. The whole thickness grafts including all of the elastic tissue showed the largest amount of shrinkage, which was 43.60 per cent. The half thickness grafts consisting of only a portion of the

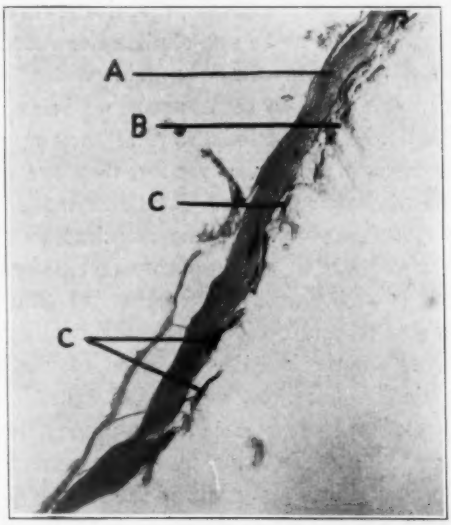

Fig. 9.—Photomicrograph of a section of a thick Ollier-Thiersch graft stained with Weigert's stain to bring out the elastic tissue. *A* indicates epithelium; *B*, papillae of the corium; *C*, elastic fibers.

corium with about half of its elastic tissue showed a shrinkage of 24.86 per cent. The thick Ollier-Thiersch grafts containing only the finest network of elastic tissue of the papillary layer of the corium had a shrinkage of 11.81 per cent. The true Ollier-Thiersch grafts which contained only the tips of the papillae of the corium and no elastic tissue had a shrinkage that ranged up to 2 per cent, which might well be considered an error of manipulation.

If this percentage of error is subtracted from the other three results, we feel justified in saying that whole thickness grafts have a shrinkage of 41 per cent; half thickness grafts, 22 per cent, and thick Ollier-Thiersch grafts, 9 per cent, while true Ollier-Thiersch grafts have no actual shrinkage.

THE RELEASE OF PERICARDIAL ADHESIONS*

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A review of the literature shows that the operations for the release of pericardial adhesions have been rather arbitrarily divided into two types: (*a*) operations that relax the adhesions between the pericardium and the surrounding structures, and (*b*) operations that remove a portion of the leather-like pericardium from around the heart and release the adhesions between the pericardium and the heart, if any such adhesions are present. The more one studies the question of adhesions of the pericardium, the more one is convinced that these two types are but the continuation of the same process. It is unfortunate that custom has divided these operations so that they appear as designed for two different diseases, when, in reality, they are designed to meet different stages of the same process. It is still more unfortunate that the names of men should have become attached to these operations. The following is a partial list of the many confusing terms found in the literature: boning of the wall of the chest for adhesive pericarditis, cardiolysis, Brauer's operation, cardiolysis for mediasternopericarditis, pericardiolysis, Rehn's operation, decortication of the heart, Delorme's operation, Schmieden's operation, pericardial resection, the relief of obstruction to circulation in a case of chronic constrictive pericarditis, precordial resection of the rib for adhesive pericarditis, resection of the pericardium in concretion, resection of the pericardium in accretion, precardial thoracectomy, lysis of intrapericardial adhesions, thoracolysis praecordiaca, and Sauerbruch's operation.

The term "cardiolysis," from its derivation ("kardio," heart; "lysis," loosening), should include all those procedures that have to do with the loosening of the heart, but usage confines this term to operations for removal of the cartilaginous and bony obstructions to the cardiac impulse in cases of chronic mediastinopericarditis. For many years, adherent pericarditis has been found at postmortem examinations. It has been diagnosed correctly by clinicians and ineffectively treated by various drugs, as only temporary relief can be obtained by the employment of habit-forming drugs and cardiac rest.

Churchill[1] quoted Wiell as saying the following in 1895:

> After the adhesions have reached a fibrous stage, they act independently of their original cause, and medical therapy is illusory. One has never dreamed of

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1. Churchill, E. D.: Decortication of the Heart (Delorme) for Adhesive Pericarditis, Arch. Surg. **19**:1457 (Dec.) 1929.

attempting a debridement in such a case, less perhaps from resignation than from the uncertainty of diagnosis. There would be good cause to make an attempt of this kind, designed to liberate a part of the heart, the apex for example, and the anterior surface . . . . It will one day come within the province of surgery to deliver the heart from the shell which strangles it.

In 1898, Delorme [2] stated in detail the operation that he thought should be done for the release of adhesions between the heart and the pericardium. This is now known essentially as Delorme's operation for decortication of the heart.

At the meeting of the American Medical Association in 1901, as a part of a symposium on pericarditis, Dr. Babcock [3] read a paper on "Adherent Pericarditis." During the discussion following this symposium, Dr. Carl Beck is quoted as having said: "I should like to ask Dr. Babcock as to the advisability, in cases of adherent pericarditis, of approaching the adhesions with the surgeon's knife." As far as I can ascertain, this is the first time the question of application of surgical measures for the relief of symptoms due to adherent pericarditis was raised in America. From this quotation, it must be concluded that Dr. Beck was most indefinite as to the method of applying "the surgeon's knife."

It remained for Rehn [4] in 1913 to carry out Delorme's theories. Rehn's four patients were unfortunately selected, as two of them were tuberculous and the other two, though benefited, lived only two years following the operation.

Even before Rehn [4] attempted to carry out Delorme's theories, Brauer,[5] professor of medicine at Marburg, evidently realized that so formidable an operation would never be popular, so he proposed to Petersen [6] the removal of the ribs and cartilages that were resisting the apparent systolic beat and diastolic tug at the apex. This operation is now generally known as Brauer's cardiolysis operation for the release of chronic mediastinopericardial adhesions.

In 1907, Wenckbach [7] performed the first operation of the Brauer type done in England. In 1912, Summers [8] performed the first operation of this type done in America, for adherent pericarditis.

A review of the literature up to January, 1930, shows that the operation of decortication of the heart for adherent pericarditis has been done, or attempted, in thirty-seven cases. Table 1 is a partial copy of Churchill's complete review. To this list I have added one

2. Delorme, E.: Gaz. d. hôp. **71**:1150, 1898.
3. Babcock, Robert H.: J. A. M. A. **37**:1578 (Dec. 14) 1901.
4. Rehn, L.: Berl. klin. Wchnschr. **1**:241, 1913.
5. Brauer, L.: München. med. Wchnschr. **1**:982, 1902.
6. Brauer, L.: Arch. f. klin. Chir. **71**:258, 1903.
7. Wenckbach, K. F.: Brit. M. J. **1**:63 (Jan. 12) 1907.
8. Dum, A. D., and Summers, J. E.: Am. J. M. Sc. **145**:74, 1913.

TABLE 1.—*Results in Forty-three Cases Following Decortication of the Heart for Adherent Pericarditis*

Author	Age	Result
1. Rehn: Berl. klin. Wchnschr. 1: 241, 1913	..	Excellent but temporary; tuberculous
2. Rehn: Med. Klin. 16: 234, 1920	6	Excellent but temporary; tuberculous
3. Rehn: Berl. klin. Wchnschr. 1: 241, 1913	13	Excellent; died of rheumatic fever
4. Rehn: Ibid.	14	Excellent; died 1½ years later of influenza
5. Sauerbruch: Die Chirurgia der Brustorgane, Berlin, Julius Springer, 1925, vol. 2	28	Excellent; well for 11 years
6. Sauerbruch: Ibid.	21	Died 18 days after operation of cardiac insufficiency
7. Sauerbruch: Ibid.	28	Died 24 days after operation of cardiac insufficiency
8. Sauerbruch: Ibid.	39	Excellent; died in four years; renal tuberculosis
9. Volhard and Schmieden: Klin. Wchnschr, 2: 5, 1923	..	Right ventricle torn; operation not completed
10. Volhard and Schmieden: Ibid.	..	Right ventricle torn; operation not completed
11. Volhard and Schmieden: Ibid.	..	Right ventricle torn; operation not completed
12. Volhard and Schmieden: Ibid.	..	Weak girl; died soon after operation
13. Volhard and Schmieden: Ibid.	..	Weak boy; died 14 days after operation of tuberculosis
14. Volhard and Schmieden: Ibid.	..	Died; postmortem examination showed heart still encased
15. Volhard and Schmieden: Ibid.	30	Excellent; patient well for 4 years
16. Volhard and Schmieden: Ibid.	46	Excellent; patient well for 4 years
17. Schmieden: Zentralbl. f. Chir. 51: 46, 1924	22	Died in 3 weeks
18. Schmieden and Fischer: Ergebn. d. Chir. u. Orthop. 19: 98, 1926	18	Excellent
19. Schmieden and Fischer: Ibid.	18	Died on table
20. Schmieden and Fischer: Ibid.	..	Improved
21. Schmieden and Fischer: Ibid.	5	Improved
22. Bittroff: München. med. Wchnschr. 71: 517, 1924	18	Improved; Talma's operation later
23. Delagenière: Gaz. d. hôp., 1913, vol. 86	28	Improved
24. Guleke and Lommel: Klin. Wchnschr. 4: 737, 1925	27	Excellent
25. Kirschner and Matthes: Deutsche med. Wchnschr. 52: 221, 1926	22	Excellent
26. Koennecke: München. med. Wchnschr. 74: 675, 1927	21	No improvement
27. Koennecke: Ibid.	9	Excellent
28. Grote: Mitt. a. d. Grenzgeb. d. Med. u. Chir. 38: 556, 1925	20	Excellent
29. Ljungdahl and Tengwall: Acta chir. Scandinav. 59: 480, 1926	46	Excellent
30. Enderlen: Zentralbl. f. Chir., 1925, p. 589	19	Improved for 3 months; died
31. Lilienthal: Thoracic Surgery, Philadelphia, W. B. Saunders Company, p. 422	31	Calcified pericardium; slow recovery
32. Hanebuth and Naegeli: Med. Klin. 23: 1253, 1927	..	Died 1 hour after operation
33. Lawen and Matthes: Deutsche med. Wchnschr., 1928, vol. 54	24	Improved
34. Cutler and Beck in Nelson's Loose-Leaf Living Surgery, New York, Thomas Nelson & Sons	..	Died 1 hour after operation
35. Churchill: Arch. Surg. 19: 1457 (Dec.) 1928	18	Excellent
36. Delorme and Hallopeau: Progrès méd., 1924, p. 457	16	Excellent
37. Delorme and Hallopeau: Ibid.	7	Recovery
38. Author's case	29	Striking improvement for days; died of tuberculosis
39. Bigger: Personal communication, 1930	25	Good cardiac result in spite of tuberculous peritonitis
40. Bigger: Ibid.	36	Died 12 hours after operation due to injury to right ventricle
41. Whittemore: Arch. Surg. 21: 1059 (Dec.) 1930	..	Excellent
42. Beck and Griswold: Arch. Surg. 21: 1064 (Dec.) 1930	13	Excellent
43. Eloesser: Arch. Surg., Dec., 1930, vol. 1	..	Died in 4 months of tuberculosis

case of my own, two from the service of Dr. I. A. Bigger, formerly of the Vanderbilt University, one from the service of Dr. Wyman Whittemore, one reported by Beck and Griswold and one by Dr. Leo Eloesser.

From table 1 it will be seen that in the forty-three cases there were eight operative deaths; in nine cases the operation was not completed

due to accidents during operation; in six the patients died in less than one month; in fourteen the patients were relieved for over one year, the longest period reported being eleven years; in one of the cases in which the operation was completed there was no improvement, and tuberculosis was found in eight cases.

I was able to find only fifty-four definite cases in which the bony portion of the chest was removed for the relief of symptoms due to adhesions associated with mediastinopericarditis. This procedure is usually known as the Brauer operation. Table 2 gives the results in these cases:

TABLE 2.—*Results in Fifty-Four Cases Following Brauer's Operation*

Author	Age	Result
1. Brauer: Verhandl d. deutsch. Gesellsch f. Chir. 32: 86, 1903	50	Excellent
2. Brauer: Ibid	25	Excellent
3. Brauer: Ibid	16	Excellent
4. von Beck: Arch. f. Chir. 77: 958, 1904	21	Fair; tuberculous
5. von Beck: Ibid	32	Poor; tuberculous
6. von Beck: Ibid	19	Excellent
7. Trempel: München. klin. Wchnschr., 1905, vol. 22	22	Excellent
8. Meyer-Wistfeld: Ibid	24	Excellent
9. Umber: Therap. d. Gegenw. 46: 10, 1905	Adult	Relief for 2 years; tuberculous
10. Danielsen: Beitr. z. klin. Chir., 1906, vol. 51	20	Excellent
11. Umber: Deutsche med. Wchnschr. 33: 1907	42	Excellent
12. Wenckbach: Brit. M. J. 1: 63, 1907	14	Relief for 1 year; probably tuberculous
13. Urban: Wien. med. Wchnschr. 58: 391, 1908	22	Improved; tuberculous
14. Enzgraber and Schovargenauer: Arch. d. mal. du coeur, 1909, vol. 2	16	Excellent
15. Ensgraber and Schovargenauer: Ibid	29	Excellent
16. Poynton and Trotter: Proc. Roy. Soc. Med., June, 1909	16	Excellent
17. Soyesima: Deutsche Ztschr. f. Chir., 1909, vol. 98	21	Excellent
18. von Togic: Wien. klin. Wchnschr., 1909, vol. 22	31	Excellent
19. Southerland: Proc. Roy Soc. Med., 1910-1911	26	Excellent
20. Schlayer: München. med. Wchnschr. 57: 729, 1910	32	Died 12 hours after operation
21. Schlayer: Ibid	49	No improvement
22. Schlayer: Ibid	19	No improvement
23. Thorburn: Brit. M. J. 1: 10, 1910	29	Excellent
24. Simon: Brit. M. J. 2: 1649, 1912	15	Improvement for 1 year; died
25. Summers: Am. J. M. Sc., Jan., 1913	29	Improvement for 4 years
26. Summers: Ibid	23	Improvement for 9 months
27. Hobst: Norsk mag. f. laegevidensk., Oct., 1914	22	Excellent
28. Hobst: Ibid	31	Excellent
29. Love-Tosserand and Penn: Soc. méd. d. hôp., 1914	7	Excellent
30. Counant-Gortere: Ibid	28	Excellent
31. Hirschfelders: Diseases of the Heart and Aorta, p. 618	23	Good
32. Smith, E. S.: Med. Clin. North America 4: 835, 1920	41	Death in 20 days
33. Smith, E. S.: Ibid	38	Excellent
34. Hallopeau: Bull. et mém. Soc. d. chir. 47: 1120, 1921	16	Excellent
35. Schmelden: München. med. Wchnschr. 69: 177, 1922	46	Excellent
36. Dunant and Turrettini: Schweiz. med. Wchnschr. 53: 606, 1923	33	Excellent
37. Graham, E. A.: Arch. Surg. 8: 345 (Jan.) 1924	..	Excellent
38. Marvin and Harvey: J.A.M.A. 82: 1507 (March 10) 1924	26	Excellent
39. Spangenberg: Semana méd. 32: 37, 1925	Not given	Successful
40. Leo: Northwest Med. 24: 285, 1925	38	Excellent
41. Stolte: Beitr. z. klin. Chir. 136: 368, 1926	6	Excellent
42. Stolte: Ibid	9	Excellent
43. Stolte: Ibid	15	Excellent
44. Stolte: Ibid	9	Excellent
45. Stolte: Ibid	8	Improved
46. Ronslacroix: Marseille méd., 1929, vol. 66	42	Excellent
47. Ronslacroix: Ibid	24	Excellent
48. Ronslacroix: Ibid	31	Death
49. Ronslacroix: Ibid	36	Excellent
50. Ronslacroix: Ibid	28	Excellent
51. Corylios: Arch. Surg. 19: 1482 (Dec.) 1929	Not given	Excellent
52. Corylios: Ibid	Not given	Excellent
53. Corylios: Ibid	Not given	Excellent
54. Cole, in discussion on Beck and Griswold: Arch. Surg. 21: 1113 (Dec.) 1930		Excellent

In addition to these cases, Kob [9] reported twelve cases in children. While his results were excellent, he expressed the belief that the more extensive operation of Delorme might have to be done later in some of the cases. He reported no deaths.

In 1907, Danielsen [10] reported nine cases and was much impressed with the necessity of careful selection of cases for operation, particularly as regards testing the ability of the heart to improve.

In 1908, Venus [11] reviewed seventeen cases from the literature, in which there was an improvement in every case.

In 1909, Lecèrne [12] reported twenty cases collected from the European literature. This series showed excellent results in seventeen, and no deaths. Mouriguand,[13] in the same year, collected eighteen cases from the French literature, in sixteen of which the results were most successful; in two the operation failed to benefit, but there were no deaths. He expressed the belief that all cases of adherent pericarditis may be divided into two classes: (*a*) those diagnosed before death in which no adherent pericarditis was found post mortem; (*b*) those not diagnosed before death in which adherent pericarditis was found post mortem.

In 1910, Roux-Berger [14] reported thirty cases from the European literature. In twenty-one of these cases the operation was successful; in seven it was a failure and in two the results were only fair; there were no deaths. He expressed the belief that before the operation was done the myocardium should be tested as advocated by Danielsen. Most authors do not agree with this view, for, while the prognosis is worse in cases in which the myocardium is affected, the operation offers the only possible hope for relief. After the release of adhesions, the myocardium has been shown to improve greatly in those cases in which the patients had had rest and digitalis previous to operation.

In 1910, Schlayer [15] reviewed the late results in twelve cases and expressed the belief that the immediate good results were not of long duration. He further expressed the belief that the operation was more successful in those cases that exhibited a tendency toward the development of polyserositis.

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9. Kob, M.: Jahrb. f. Kinderh. **65**:643 (June) 1907.
10. Danielsen, W.: Beitr. z. klin. Chir. **54**:458, 1907.
11. Venus: Centralbl. f. d. Grenzgeb. d. Med. u. Chir. **11**:401, 461, 489, 537, 1908.
12. Lecerne, P.: Arch. d. mal. du coeur **2**:673 (Dec.) 1909.
13. Mouriguand, C.: Lyon chir. **2**:781 (Dec.) 1909-1910.
14. Roux-Berger, J. L.: Semaine méd. **30**:423 (Sept. 7) 1910.
15. Schlayer, K.: München. med. Wchnschr. **57**:729 (April 12) 1910.

In 1922, Klose [16] reported operations on sixteen children, seven of whom died. He expressed the belief that the results would be better if adhesions were prevented by careful management of the child during the acute "rheumatic" attack. In four cases he patched the pericardial defect with fat and fascia from the thigh. He experimented on nineteen dogs and found that a flap of fat worked better than fascia, peritoneum or omentum. He further tried various chemicals to prevent reformation of adhesions, but came to the conclusion that such were useless. From the description of the operation, it would appear that he included some procedures for decortication of the heart and some for release of the pericardium from surrounding structures.

It is impossible to state how many of the cases reported by Kob, Venus, Mouriguand, Danielsen, Roux-Berger, Schlayer and Klose are duplicated, and, for that reason, they are not included in table 2. I think it is conservative to estimate that over 100 have been reported in the literature, though, for the foregoing reason, it is impossible to state the exact number.

Graham [17] stated his belief that there are "literally hundreds" of these cases in which surgical relief is not being given.

For many years adhesive pericarditis has been known to pathologists, and it is interesting to note the frequency with which the different types of pericarditis have been found at necropsies.

Brooks and Lippencott [18] stated:

> Morgagni and Vieussens described the obliterative type of pericardium, and Corvisant in 1811 noted the significance of the bulging pericardium. Although Laennec was familiar with the lesion, he expressed his doubts as to the possibility of diagnosis. The characteristic to-and-fro rub of the acute condition was not recognized until 1824 by Collis.

Galen described the absence of the pericardium. A study of the literature on the pericardium also discloses a number of cases showing various degrees of congenital pericardial deficiencies. In an editorial in the *Journal of the American Medical Association*, Feb. 26, 1916, Keno of the Institute of Physiology, University College, London, is quoted as having proved that the pericardium was a valuable support to the heart. Keno further thought that the heart could be dilated almost to the point of rupture if it was overworked after the removal of the pericardium.

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16. Klose, H.: Arch. f. klin. Chir. **119**:455 (Jan. 1) 1922.

17. Graham, E. A., in discussion on Alexander, J.; MacCleod, A. G., and Barker, P. S.: Sensibility of the Exposed Human Heart and Pericardium, Arch. Surg. **19**:1480 (Dec.) 1929.

18. Brooks, H., and Lippencott, L.: Am. J. M. Sc., 1909, vol. 138.

On the other hand, Moore,[19] in 1925, collected sixty-four cases of congenital pericardial defects, and in none of these cases were there any symptoms that could be attributed to such defects. The defects are found on the left side in the vast majority of cases; in fact, in only one of the forty-two cases reviewed was the defect on the right side. Moore advanced a most interesting reason for this, based on embryology. He concluded that the existence of the pericardium is not necessary for the unimpaired function of the heart during the normal life. However, he did feel that the pericardium protects the heart from adhesions.

Grant,[20] in 1926, reported finding at necropsy a pericardial defect in a man 52 years of age who had worked hard during his life, but had not had any cardiac symptoms. Grant came to the conclusion that the absence of the pericardium is not a factor in connection with cardiac enlargement, and he expressed the belief that the pericardium played no part in the support of the cardiac wall.

Stone [21] reported on 300 necropsies following pneumonia; some form of pericarditis was found in 72, or 24 per cent. Fourteen cases, or 5 per cent, showed what was classified as "fibrinplastic" pericarditis.

Hobst [22] found adherent pericarditis in sixty-one cases, which was 4 per cent of all routine necropsies. It is interesting to know that in thirty of these sixty-one cases no valvular defects were found.

In 1901, McFarland [23] quoted Breitung as having collected "324 cases of pericarditis among the autopsies of the Berlin Charite, between the years 1866 and 1876." He did not give the total number of necropsies done during that period. However, 133, or 44 per cent, of these cases of pericarditis were found to be of the adhesive type.

In 1909, Fenton [24] reviewed 150 fatal cases of adherent pericarditis and found that in 82 death had occurred from symptoms directly dependent on the heart while in 68 death had occurred from symptoms not connected with the heart.

From these and other somewhat similar reports, it may be concluded that adherent pericarditis is not so infrequent as is generally supposed, and that the disease has been known for a long number of years.

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19. Moore, R. L.: Congenital Deficiency of the Pericardium, Arch. Surg. **11**: 765 (Nov.) 1925.

20. Grant, R. T.: Heart **13**:371 (Dec. 23) 1926.

21. Stone, W. J.: Pericarditis as Complication in Pneumonia, J. A. M. A. **73**:254 (July 26) 1919.

22. Hobst, P. F.: Norsk mag. f. lægevidensk. **7**:1, 1908.

23. McFarland, Joseph: The Pathology and Pathogenesis of Pericarditis, J. A. M. A. **37**:1507 (Dec. 7) 1901.

24. Fenton, W. J.: Practitioner **81**:637 (Nov.) 1908.

It is usually regarded that the unknown cause of rheumatism, or, in the nomenclature of today, "arthritis from focal infections," is the chief etiologic factor in the production of these adhesions. However, in a brief review of some of the literature, I noted that various types of streptococci, pneumococci and staphylococci, and of tuberculosis, gonorrhea and influenza bacilli, etc., have been reported as being intimately connected with the causation of adherent pericarditis.

MacCallum [25] stated that bacteria are usually considered to infect the pericardium by the way of the blood stream, "since it is difficult to trace a direct extension from pleural infection and such pleurisies occur so often without pericarditis." However, Stone [21] showed that pericarditis occurred twice as frequently following pneumonia on the left side as it did on the right. Whittemore reported a case of pneumococcus pericarditis with adhesions. He opened the pericardium (after aspiration had failed to give any aid), released adhesions, and after liberating pus, closed the incision with drainage; the patient made a rapid recovery. MacCallum [25] further stated that "endocardial and myocardial infection may also extend to the pericardium."

Adhesions are usually the end-results of a defensive process, and, therefore, it would be unusual to find any definite organism late in the disease. Of course, in purulent pericarditis, all the aforementioned bacteria and others have been found. Any one who is interested in purulent pericarditis will find this subject fully and most attractively discussed by Winslow and Shipley.[27] They collected 118 cases of suppurative pericarditis and added 10.

Darrach [28] instituted drainage in a case of purulent pericarditis (the type of infection not stated), and the patient remained well for two years. Then he returned with an adherent pericardium, from which he died.

There have been six cases of primary tuberculous pericarditis reported in literature since 1900. In 1904, Scagliosi [29] found 1 case in 1,077 necropsies; this occurred in a woman 60 years of age. In 1906, McGavean [30] reported a case in a woman 56 years of age. In 1925,

25. MacCallum, W. G.: Pathology, Philadelphia, W. B. Saunders Company, p. 229.

26. Footnote 26 was deleted by the author.

27. Winslow, Nathan; and Shipley, A. M.: Pericardiotomy for Pyopericardium, Arch. Surg. **15**:317 (Sept.) 1927.

28. Darrach, William, in discussion on Poole, E. H.: Ann. Surg. **73**:393 (April) 1921.

29. Scagliosi, S.: Deutsche med. Wchnschr. **30**:873 (July 9) 1904.

30. McGavean: Columbus M. J. **30**:345 (June) 1906.

Rawls [31] reported a case. In 1928, Roubier and Langĕnieux [32] reported 2 cases. In 1928, Alston [33] reported a case in a man of 70 years.

In 1909, Gibson [34] made an incision and instituted drainage in a case of tuberculosis of the pericardium with apparent success. Gibson does not know how long this patient remained well, for he disappeared from observation, but he remained free from symptoms for several years.

In 1926, Castex, Carelli and Gonzalez [35] injected iodized poppy seed oil 40 per cent in a case of tuberculous pericarditis to determine the presence of adhesions. They thought the procedure was of both therapeutic and diagnostic value.

In 1929, Ackermann [36] injected air and iodized oil into the pericardial sac of a patient with tuberculous pericarditis and reported much improvement in the patient's condition.

Thayer [37] reported a case of tuberculous pericarditis in which 1,200 cc. of fluid was removed by pericardial puncture. Thayer was able to follow this case for longer than three years, and after the acute process had subsided, an adhesive pericarditis without fluid developed. This case would at least suggest that an adherent pericarditis is the end-result of a tuberculous process in some cases.

Brooks and Lippencott [18] stated that the same conditions that are found relative to tuberculous pericarditis pertain also to pericarditis due to syphilis.

The older writers often considered pericarditis to be due to some toxic condition, and it was in this connection that Bright reported the association of pericarditis and nephritis. It is more than likely that those cases reported by Bright were cases in which the same organism caused both the nephritis and the pericarditis.

In 1902, MacLachlan [38] published an extremely instructive paper on tuberculosis of the pericardium and gave a complete bibliography.

In 1901, Wells [39] demonstrated 10 cases of tuberculous pericarditis in 1,048 autopsies and concluded that this condition developed in about

31. Rawls, W. B.: Primary Tuberculous Pericarditis, Am. J. M. Sc. **169**:815 (June) 1925.

32. Roubier, C., and Langĕnieux, J.: Lyon méd. **142**:213 (Aug. 19) 1928.

33. Alston, J. M.: Edinburgh M. J. **35**:116 (March) 1928.

34. Gibson, C. L.: M. Rec. **76**:216 (Aug. 7) 1909; personal communication.

35. Castex, M. R.; Carelli, H. H., and Gonzalez, H. D.: Bull. et mém. Soc. méd. d hôp. de Paris **50**:217 (Feb. 12) 1926.

36. Ackermann, W.: Am. Rev. Tuberc. **20**:236 (Aug.) 1929.

37. Thayer, W. S.: Bull. Johns Hopkins Hosp. **15**:149 (May) 1904.

38. MacLachlan, W. W. G.: New York State J. Med. **22**:45 (Feb.) 1922.

39. Wells, H. G.: The Pathology of Active Tuberculosis of the Pericardium, J. A. M. A. **36**:1451 (May 25) 1901.

5 per cent of all cases of active tuberculosis. He further came to the conclusion that tuberculosis of the pericardium in the adherent form was a rare occurrence.

Norris,[40] on the other hand, after a somewhat similar study, concluded that tuberculosis accounted for a large number of those adherent lesions. He further considered that these adhesions represented, in many instances, healed tuberculous lesions that could not be demonstrated by histologic studies, but by inference.

MacLachlan [38] stated, "It seems rather strange that calcification, a cardinal sign of healed tuberculosis, when it occurs in the pericardium, very rarely means this disease." It is interesting to note that the report by Cutler and Sosman,[41] in which they reviewed two cases of calcification of the pericardium, showed that one of these cases was definitely tuberculous in origin, while in the other one, they concluded that the "process must represent the late stage of healing of the infection." Unfortunately, full clinical data could not be obtained in this case.

In 1927, Taylor [42] reported a case in which the "influenza" bacillus was isolated from the pericardial fluid in pure culture.

In 1905, Huber [43] reported a case of acute gonorrheal pericarditis, and in 1909, Bubis [44] also reported a case of this type.

The pericardium and its adhesions do not differ from other structures in the late development of calcareous deposits and infiltrations. The literature shows ninety-six cases reported.

In 1923, Case [45] reported ninety cases from the literature, to which he added one. In his report he gives a list of all the references. Since this time the following five cases have been reported: Schlesinger,[46] one case in 1926; Kirschner and Matthes,[47] one case in 1926; Arnesen,[48] one case in 1927, and Starck,[49] two cases in 1928. In these cases of calcareous pericarditis there have been four attempts to remove a part of the stonelike pericardium. The results have not been entirely successful.

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40. Norris: Univ. Pennsylvania M. Bull., 1904, vol. 17.

41. Cutler, E. C., and Sosman, M. C.: Am. J. Roentgenol. **12**:312 (Oct.) 1924.

42. Taylor, Ruth E.: Influenzal Pericarditis, J. A. M. A. **89**:347 (July 30) 1927.

43. Huber, F.: Arch. Pediat. **21**:919, 1904.

44. Bubis, J. L.: Cleveland M. J., December, 1909.

45. Case, James T.: Pericarditis Calculosa, J. A. M. A. **80**:236 (Jan. 27) 1923.

46. Schlesinger, H.: Med. Klin. **22**:11 (Jan. 2) 1926.

47. Kirschner, M., and Matthes, M.: Deutsche med. Wchnschr. **52**:221 (Feb. 5) 1926.

48. Arnesen, J.: Norsk mag. f. laegevidensk. **88**:688 (Aug.) 1927.

49. Starck, H.: Med. Klin. **24**:1736 (Nov. 9) 1928.

In 1923, Lilienthal [50] reported a case of calcified pericardium in which he attempted to remove the stonelike structure. Before completing the operation, he injured the auricle and was, therefore, unable to continue. The patient slowly recovered with a persistent sinus tract. Lilienthal further stated, "If I were to operate in another case, I should begin removal of the calcified pericardium over the cardiac apex gradually working up toward the thinner and more dangerous region of the auricle." This patient (personal communication from Dr. Lilienthal) lived over a year. She did not die in the hospital, and no postmortem examination was allowed.

In 1923, Cutler and Sosman [41] removed a portion of a calcified pericardium. This was found to be so difficult as to require the use of rongeurs. They found the calcification also involving the myocardium. The patient died in twenty-four hours. These authors also reported two other cases in which on autopsy the calcification was found to extend not only to the myocardium, but it also involved the diaphragm. They mentioned another case in which roentgenoscopic examination showed "calcification in the region of the mitral valve." This case gave no "evidence that the calcification has any particular significance."

All the authors who have discussed calcification of the pericardium, since the advent of the x-rays, have stressed the importance of utilizing this agent in the diagnosis of this condition.

With the heart embarrassed by adhesions, it is not surprising to find hepatic changes and serous cavities filled with fluid. In these cases the liver is usually three or four times its normal size, and the condition is sometimes referred to as Pick's pericardiac pseudocirrhosis. Much has been written on the pathologic changes in the liver and other morbid processes associated with chronic mediastinopericarditis and adherent pericarditis. Any one particularly interested in such studies is referred to textbooks by Pick,[51] Rolleston,[52] Hirschfelder,[53] and Smith,[54] all of whom have written full descriptions of the pathologic changes in the various organs, which are due to the cardiac failure dependent on pericardial adhesions.

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50. Lilienthal, H.: Thoracic Surgery, Philadelphia, W. B. Saunders Company, 1926, vol. 2.

51. Pick, F.: Ztschr. f. klin. Med. **29**:385, 1896.

52. Rolleston: Diseases of the Liver, Gallbladder and Bile Ducts, New York, The Macmillan Company, 1912.

53. Hirschfelder, A. D.: Diseases of the Heart and Aorta, ed. 2, Philadelphia, J. B. Lippincott & Company, 1913.

54. Smith, E. S.: M. Clin. North America **4**:835 (Nov.) 1920.

It is interesting to recall that Rohde [55] produced experimentally a stenosis of the vena cava at the site between the pericardium and the diaphragm, which gave many of the results of an adherent pericardium, such as enlarged liver, ascites and polyserositis.

Before the association between the pericardial adhesions and the enlarged liver was as well understood as it is today, it was thought that Talma's operation on the liver might be of value. Clemens [56] thought that he noticed temporary improvement in the one case in which he did this operation. However, Smith [54] reported a case of chronic mediastinopericarditis in which Talma's operation had been done without any benefit. These two cases serve to show how it is possible for symptoms due to enlarged liver to mislead one unless the possibility of an adherent pericarditis is kept in mind.

Bittrolff [57] did Talma's operation on a patient on whom he had previously performed the Delorme operation with complete relief from the abdominal symptoms.

It is essential to be able to differentiate between the symptoms due to an enlarged liver resulting from myocardial and valvular cardiac disorders and those symptoms due to an enlarged liver resulting from pericardial adhesions. Some authors stated that when an enlarged liver is found and this enlargement is due to the heart and no valvular disease is located, then the symptoms must be due to adherent pericarditis.

AIDS TO DIAGNOSIS

When the morbid anatomy is so well understood and the operative relief so thoroughly described, there must be some reasons why surgical aid is not sought more often. I think these reasons may be found in the uncertainty and difficulty of diagnosis, as well as in the general lack of appreciation of beneficial results of certain operative procedures which have not received the credit they deserve.

The making of the diagnosis of pericardial adhesions does not differ from many other diseases in that carefully taken and honestly analyzed history is of prime importance. For example, in examining a patient who has had some serious infection in youth, such as is usually called "rheumatism," who develops an enlarged liver, is easily exhausted and presents no cardiac murmurs, the diagnosis of adherent pericardium should be given serious consideration. It would be of great aid to remember that any infection in youth that continues longer

55. Rohde, C.: Deutsche Ztschr. f. Chir. **203-204**:18, 1927.
56. Clemens, P.: München. med. Wchnschr. **1**:936, 1903.
57. Bittrolff, R.: München. med. Wchnschr. **71**:517, 1924.

than is usual and is unexplained by some more plausible reason than "lowered resistance" might have been a pericarditis, which later in life produced the symptoms of an adherent pericarditis.

In 1929, Dr. Evelyn Holt [58] of the cardiac clinic of New York Hospital stated that "in 1898 Sir John Broadbent said that the key to the solution of the problem of adherent pericardium seemed to lie in the investigation of cases of pericarditis which could be kept under observation while going on to the formation of adhesions." With this in view, she studied fifty-one cases of chronic adhesive pericarditis in children. Only six of these patients are leading a reasonably normal life. Twenty-one died within four years, and sixteen are apparently growing worse. She was unable to trace eight. It is probable that a fairly large percentage of the six persons who are now leading a "reasonably normal life" will later develop some type of adhesive pericarditis, and unless a careful history is taken, this possibility will be overlooked.

The symptoms are usually insidious in origin and develop slowly, sometimes over a period of years. Frequently the patient complains of pain in the region of the heart, and this is often exaggerated on exertion. If the disease is allowed to progress, many other symptoms are added as the various other organs become involved.

Musser and Herrmann [59] reviewed 1,720 necropsies, 305 of which showed various types of pericarditis. From a careful analysis of the clinical history in 68 of the 305 cases, they felt that death was due directly to pericardial involvement. They also produced adhesive pericarditis in dogs by injecting permutit into the pericardium and then observing the dogs for "any one or more conditions that would invariably indicate pericardial disease." Their conclusions are as follows:

1. It is generally agreed that adhesive pericarditis is rarely diagnosed ante mortem.

2. There are no pathogenic signs found in all cases.

3. The diagnosis depends in part on the history, to which is added a thorough survey of the physical signs and the electrocardiographic and roentgenologic examinations.

4. Experimental pericarditis has not yielded any positive information.

In nearly one half of the cases of adhesive pericarditis there are also found either myocardial changes or cardiac valvular disease. Not

58. Holt, Evelyn: Am. J. M. Sc. **178**:615 (Nov.) 1929.

59. Musser, J. S., and Herrmann, G. H.: Chronic Pericarditis, J. A. M. A. **87**:459 (Aug. 4) 1926.

infrequently is there a combination of all three of these complications. Occasionally, the patient's attention is first attracted by the fulness and firmness of the abdomen and an enlarged liver. It is possible, at this time, that the patient has no edema of the legs. An examination of the urine is negative, except possibly for the presence of a little bile, and the heart sounds disclose no murmurs. This picture should make every physician suspicious of pericardial adhesions.

Beck and Griswold [60] actually "champion diagnostic pericardiotomy in selected cases of circulatory failure of obscure cause."

It will be of aid to remember that adherent pericarditis is a progressive disease, and therefore the symptoms will vary with the type, extent and location of the adhesions. At the apex of the heart, there is frequently a systolic tug or retraction with a diastolic shock or rebound. It is of much importance to note that the apex beat does not change its position when the patient is turned from side to side. This is even true if the patient is allowed to stand. Regelsberger [61] stated that in doubtful cases this diastolic bulging and systolic retraction is sufficient to make the diagnosis. Of course, this sign is not present when there is a leather-like shell of thickened pericardium surrounding the heart, thus preventing any cardiac impulse from reaching the thoracic wall. If the adhesions are due to a mediastinopericarditis which has extended to the back, Broadbent's [62] sign is frequently present. This sign is a "visible retraction, synchronous with the cardiac systole of the left back in the region of the eleventh and twelfth ribs."

Thayer [37] "found the third heart sound and the corresponding protodiastolic shock and wave very distinct in adherent pericardium."

Pulsus paridoxicus (Kussmaul's sign) occurs, i. e., the pulse intermits during inspiration, most often in mediastinopericarditis. This may occur in healthy subjects.

There may be peculiar movements in the great vessels of the neck as if the blood current was hindered in its flow; it gives one the impression that the ventricle is making an effort to drive the blood into those vessels but is prevented from doing so by adhesions. Of course, these arterial movements may be modified by valvular lesions. In recent years this has been shown to be caused by other conditions. Curschmann [63] suggested that this condition might be due to pressure of the scalenus minimus muscle on the subclavian artery during inspiration.

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60. Beck, C. S., and Griswold, R. A.: Pericardiectomy in the Treatment of the Pick Syndrome, Arch. Surg. **21**:1064 (Dec.) 1930.

61. Regelsberger, H.: Deutsches Arch. f. klin. Med. **147**:129 (May) 1925.

62. Broadbent, William H.: Lancet **2**:200, 1895.

63. Curschmann, H.: Med. Klin. **18**:1521 (Nov. 26) 1922.

In referring to cases "when the heart is throttled by a contracting pericardium," Churchill stated that "the most striking single characteristic of the picture is marked stasis with a small heart."

The cervical veins are frequently dilated in cases of pericardial adhesion, and should a tricuspid regurgitation develop, they pulsate. A sudden collapse of the veins of the neck during ventricular systole is often present (Friedrich's sign), and when associated with a systolic retraction of the intercostal spaces, is a very valuable sign.

Bigger [64] and his associates, Drs. Burwell and Strayborn, estimated "the venous pressure and blood flow determinations" in one of his two cases. They expected to repeat these observations after the operation, but unfortunately the patient died. Beck and Griswold [60] estimated the venous pressure in their case and found that it fell rapidly on releasing the heart from its constricting shell. They expressed the belief that venous pressure is the most reliable index of a contracting and restraining pericardium.

If the two walls of the pericardium rub at any point against each other, friction sounds can be heard. De Teyssier [65] reported one case in which there was a rather small collection of pericardial fluid that produced such friction sounds; this observation was confirmed at autopsy. The case was one of tuberculous pericarditis.

Richter [66] also reported one case of adherent pericardium in which he heard friction sounds. Autopsy disclosed old blood clots in the loose connective tissue of the pericardial adhesions, to which he attributed these friction sounds.

Another interesting sign was reported by Riess,[67] namely, loud and metallic heart sounds heard over the stomach. Riess attributed these sounds to adherence of the pericardium to the diaphragm.

Apparently, there is no sign in the diagnosis of adherent pericardium concerning which there has not been contradictory reports. The roentgenogram and the electrocardiogram are not exceptions. This discrepancy is not hard to understand, for no one person or clinic has had a sufficient number of cases to formulate any definite observations. There has been a sufficient number of cases, however, for most diagnosticians to feel that by the aid of these two agents the most reliable information available may be obtained.

In 1923, Lukin [68] reported a fluoroscopic sign of a partially adherent pericardium, which he described as a "rhythmic tug of a part of the

64. Bigger, I. A.: Personal communication, Nov. 14, 1930.

65. de Teyssier, J.: Lyon méd. **127**:499 (Nov.) 1915.

66. Richter, E.: Berl. klin. Wchnschr. **45**:821 (April 27) 1908.

67. Riess, L., quoted by Hirschfelder: Diseases of Heart and Aorta, Philadelphia, J. B. Lippincott Company.

68. Lukin, N.: A Fluoroscopic Sign of a Partially Adherent Pericardium, J. A. M. A. **81**:1952 (Dec. 18) 1923.

left dome of the diaphragm near its centre with each systole of the heart when the diaphragm was fixed in an inspiratory frame." This shadow disappears entirely in forced inspiration, the heart being separated from the diaphragm by a clear space, which corresponds to the base of the left lung, and the lower edge of which is outlined for the greater part of its length against the clearness of the pulmonary tissues. The rhythmic tug of a part of the diaphragm with each systole of the heart is distinctly visible in that clear space when the phrenum is fixed in inspiration because the visceral pericardium is adherent to the parietal pericardium, even though in a small degree, and exerts a pull on it and through its insertion on the diaphragm with each cardiac contraction.

The patient in whom this sign was observed had recovered from a serofibrinous pericarditis nine months previously. Lukin also observed the same sign in another patient who had had a "rheumatic endopericarditis" two years previously.

In 1924, Holmes [69] published his roentgen observations in sixty cases of pericarditis of various types. He stated:

> In the normal heart, it is usually possible, under the fluoroscopic observation, to differentiate the pulsations of the auricle from those of the ventricle. In the presence of pericarditis, and particularly if fluid is present, the pulsation becomes diffuse over the entire cardiac area, and it is impossible to distinguish the auricular beat from that of the ventricle. While the making of this observation requires considerable experience to be accurate, it apparently does not occur in any other cardiac condition, and when found must be considered as almost pathognomonic. This sign is especially valuable as it is present in adhesive pericarditis, as well as pericarditis with effusion.
>
> We have found that the obliteration or change in the shape of the cardiohepatic angle (Retch's sign) is more likely to occur in pericarditis with adhesions than with fluid, and that it is not a reliable finding in any case. This observation has been confirmed by other writers. . . . Other findings, such as retraction of the diaphragm with the heart beat, and fixation of the heart within the chest as shown by failure to be displaced when the patient is turned from side to side, are subject to so much error in observation by the roentgen ray that we have found them of little value.

Holmes [69] concluded by saying:

> From this data it would seem that the roentgen-ray is of considerable value in making a positive diagnosis of pericarditis, and that a negative roentgen-ray finding make a negative diagnosis probable.

In the discussion following his paper, Holmes concluded:

> I should like to mention the value of the respiratory study of the heart during adhesive pericarditis. In the lateral view, particularly if the mediastinum is

69. Holmes, G. W.: Some Observations on the Use of Roentgen Rays in the Diagnosis of Pericarditis, J. A. M. A. **83**:1745 (Nov. 29) 1924.

involved, the heart may rise with the chest wall instead of dropping with the diaphragm during forced breathing. This is a very definite and easily interpreted sign.

Chandlee and Burrill-Holmes [70] reviewed 100 cases of disease of the heart and of the great vessels in the cardiac clinics of the Philadelphia General Hospital, and I quote the following from their report:

> In chronic adhesive pericarditis, the lack of mobility of the apex is visualized on fluoroscopic examination and the heart does not show the normal shadow separating the shadow of the diaphragm on inspiration. Films occasionally show deformity of the pleuropericardial diaphragmatic shadows, and it is probably because of these adhesions that many pleuro-pericardial friction sounds are heard clinically. . . .The fluoroscopic study helps explain the low and fixed position of the apex seen particularly in mitral stenosis accompanied by pericarditis.

If the heart is surrounded by a leather-like shell, as it was in the case in which I operated, only slight, if any, cardiac movement can be seen with the fluoroscope. Of course, if the pericardium has deposits of calcium, these can be seen with the fluoroscope and shown on the plate, as has been mentioned previously.

There is normally a change in the form of the electrocardiogram on shifting the patient to the right or to the left side. This is due to rotation of the heart about a longitudinal axis. The change in the height and conformity of the QRS wave in the different leads is the most noticeable, though all the waves are affected to a certain degree. All three leads are affected but usually only leads I and III show marked variation. Dieuaide [71] has made application of this phenomenon in the diagnosis of an adherent pericardium. In curves on cases of chronic adhesive pericardial mediastinitis this normal change, shift of the electrical axis, is absent and is believed diagnostic of the condition.

In electrocardiograms of abnormalities on patients presenting suggestive signs of adhesive pericarditis other changes may be noted. These are abnormalities of the T wave, low voltage, notching and slurring of the QRS complex. However, the only change that seems directly due to adhesions is fixation of the electrical axis.

Articles concerning electrocardiographic studies by Porte and Pardee,[72] Becke, Johnson and Harris,[73] Carter and Dieuaide,[74] and Holt [58] will be found of interest and aid.

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70. Chandlee, E. J., and Burrill-Holmes, E.: Am. J. M. Sc. **178**:364 (Sept.) 1929.

71. Dieuaide, F. R.: Electrocardiograms as Aid in Diagnosis of Adhesive Pericardial Mediastinitis, Arch. Int. Med. **35**:362 (March) 1925.

72. Porte, D., and Pardee, H. E. B.: Am. Heart J. **4**:584 (June) 1929.

73. Becke, W. G.; Johnson, S., and Harris, H. S.: Am. Heart J. **2**:302 (Feb.) 1927.

74. Carter, E. P., and Dieuaide, F. R.: Bull. Johns Hopkins Hosp. **32**:219 (July) 1921.

AIDS TO OPERATION

It is not only essential to make the correct diagnosis of adherent pericardium, but also highly important to determine as accurately as possible the extent and the location of the adhesions before proceeding to undertake any type of operation. Manifestly, if the adhesions are between the pericardium and the thoracic wall, the removal of the pericardium is both dangerous and unnecessary. On the other hand, if the heart is surrounded by a leather-like shell, the removal of the ribs will not give the required relief.

The following is a suggestion, which, as far as I can find, has not been used to assist in the release of pericardial adhesions as a supplementary aid to the Brauer operation. However, since writing the foregoing paragraph, I have obtained the following quotation from Sauerbruch's [75] textbook on surgery of the thoracic organs after a search of the German medical journals had failed to reveal any such reference:

> In mediastino pericardiatis and tuberculous adhesions which exist between heart and lung on one hand and the diaphragm on the other, phrenicotomy relieves the tension and pulling and frees the patient from disagreeable discomfort. It therefore also serves as an adjunct for the operative loosening of the heart (cardiolysis). One has also thought of combating singultus by elimination of the phrenic nerve.

It is reasonable to presume that the removal of the bony resistance in the chest to the cardiac impulses gives relief only in those cases in which the adhesions are between the pericardium and the surface from which the ribs and cartilages have been removed. There are cases in which the adhesions exist between the pericardium and the thoracic wall, and also between the pericardium and the diaphragm. It is in such cases as these that I believe the removal of a segment of the left phrenic nerve will be of value.

While I have had no case of chronic mediastinopericarditis in which I could try this, I have recently had five cases in which I did avulsion of the left phrenic nerve for pulmonary tuberculosis. In each one of these cases, the heart shadow was drawn somewhat further than normal to the left and adherent to the diaphragm, e. g., the cardiohepatic angle was obliterated (Rotch's sign) by the tuberculous process. After the avulsion of the left phrenic nerve, the heart shadow returned markedly to its normal position. All these patients had been in bed for months before operation, yet, after the avulsion of the left phrenic nerve, there were a decided increase in the blood pressure and a decrease in the pulse rate. Apparently, the cases of pulmonary tuberculosis in which a phrenic avulsion has been done on the left side have improved

75. Sauerbruch, E.: Die Chirurgie der Brustorgane, Berlin, Julius Springer 1925, vol. 2, p. 694.

more satisfactorily than those in which the right phrenic nerve had been avulsed. However, there are so many other factors to be considered, that it would be impossible to draw any fair conclusions from a comparison of the two sides.

Cole reported a case done by Johns in which an avulsion of the left phrenic nerve had produced marked benefit of symptoms. Further relief was obtained by removal of the cartilages of the third, fourth and fifth ribs.

In a personal communication, Dr. John Alexander stated:

> From time to time I have casually wondered whether the results following phrenicectomy for tuberculosis should be better upon the right or the left side, and because of the press of other things, my curiosity has stopped there. I do seem to remember that one or two men in writing (I do not know the references) have mentioned a possible swinging of the heart and mediastinal organs toward the right side after a left phrenicectomy, and it is quite reasonable to suppose that any cardiac disability due to traction of mediastino-pericardial adhesions might thereby be relieved. I do not know that anyone has ever suggested the possibility of left phrenicectomy being a useful complementary operation together with a Brauer cardiolysis, nor do I recall anyone's ever having compared the results as between right and left-sided operations. In my clinic there have now been three hundred or more phrenicectomies and my casual impression is that the good, medium and poor results have been approximately equally divided between both sides. I do know that striking results have occurred on both sides.

Smith [54] stated:

> In one case of mediastinopericarditis we were fortunate enough to obtain fluoroscopically definite evidence of adherent pericardium, in our being able to see distinctly a tugging upward of the diaphragm with each cardiac systole. . . .We have not met with any allusion to this sign of systolic tugging on the diaphragm in the literature. . . .It was very apparent, during deep inspiration, that the left diaphragm was more or less fixed toward the apical shadow of the heart, being pulled upward or tugged in synchronism with each heart throb. . . .These observations were observed to be more pronounced following rotation of the patient in the semi-oblique position, while the apex shadow was in close proximity to the fluoroscopic screen.

This (tugging) was accentuated during deep inspiration, forcibly pulling the left side of the diaphragm for a distance of at least 3 cm. with each pulsation of the heart.

Hobst [22] did autopsies in two cases in which the Brauer operation had been done. There had been great relief from symptoms in one case for five years, and, in the other, for four. Then the enlarged liver, ascites, etc., returned, and after frequent tapping of the abdomen, both patients died. Necropsies showed dense adhesions between the pericardium at the apex and the diaphragm with only slight adhesions between the front of the chest from which the cartilage had been removed. The condition of the pericardium was not such as would have been benefited by the Delorme type of operation.

In 1918, Trémolières and Caussade [76] reported twenty cases of a condition to which they give the name of "phreno-pericarditis." The symptoms suggested angina pectoris, and the x-ray plates showed the heart and diaphragm soldered together. It is possible that a phrenic avulsion may have been of some aid in these cases.

It is also interesting to note that Schmieden,[77] in 1923, warned against injury to the phrenic nerve while doing the decortication of the heart. Since that time many phrenic nerves have been avulsed during the treatment of pulmonary tuberculosis and apparently without any serious consequences. In 1926, Schmieden [78] stated that injury to the left phrenic nerve was not harmful.

It should be remembered that operations on the pericardium can be done in progressive stages with far greater safety than the previous attempts at completing the operation at one time. In chronic mediastino-pericarditis with the apex of the heart pulling against the bony chest, the so-called Brauer operation should be done first. If this does not give sufficient relief, and the roentgenogram shows combating adhesions between the pericardium and the diaphragm, then the avulsion of the left phrenic nerve should be seriously considered. It is possible for the diaphragm to be so fixed by scar tissue that the paralysis of the muscles would have but little chance of relaxation. However, it is highly improbable that the diaphragm will ever be so extensively infiltrated with fibrous tissue that some muscle tissue will not remain free from such invasion. If any muscle is left not involved then a paralysis would tend toward some relaxation. It is also reasonable to presume that there must be occasions in those cases in which the pericardium is adherent to the diaphragm, when the cardiac tug is in an opposite direction to that of the diaphragm, either in ascent or descent. In other words, if these two organs do not synchronize, then there follows a conflict when they are bound together by adhesions. Paralysis of the diaphragm should certainly give control to cardiac impulses.

Welles,[79] reported the results on the pulmonary conditions in 271 cases in which phrenic avulsion had been done. He concluded that the lack of motion of the diaphragm before operation, as observed by the fluoroscope, is not a contraindication to phrenic avulsions for the diaphragm becomes elevated in spite of having been apparently fixed before operation.

Of course, neither of these procedures would be of aid in releasing the heart from a leather-like shell, but, in such conditions, the pericar-

76. Trémolières, F., and Caussade, L.: Presse méd. **26**:169 (April 4) 1918.

77. Schmieden, V.: Klin. Wchnschr. **2**:5 (Jan. 1) 1923.

78. Schmieden, V.: Surg., Gynec. & Obst. **43**:89, 1926.

79. Welles, E. S.: Phrenicectomy in Three Hundred Cases of Pulmonary Tuberculosis, Arch. Surg. **19**:1169 (Dec.) 1929.

dium can be approached in stages, if the patient's condition either requires or permits a graded and cautious delivery. In other words, each patient is necessarily "a law unto itself," and the surgical procedures will have to be made to fit not only the type and extent of the pericardial adhesions, but also the condition of the patient.

In operations on the pericardium, the choice of the anesthetic is of prime importance, but even more important than that is the selection of the proper anesthetist. Personally, I prefer ethylene administered by the closed method in thoracic surgery, because it has the following advantages:

(*a*) It does away largely with psychic shock of a local anesthetic.

(*b*) In case the pleura is opened, the opening can be closed and the lung expanded from the rebreathing bag.

(*c*) With nitrous oxide, the patient with a pulmonary condition becomes more cyanotic.

(*d*) Ethylene does not apparently tend to "light up" old pulmonary lesions as other anesthetics do.

(*e*) "Avertin" keeps the patient asleep for several hours after the completion of the operation and thus allows aspiration into the right lung from the compressed left lung.

In the Brauer operation, the incision is started over the third rib about 5 inches (12.7 cm.) from the sternum and carried over the rib to the midline of the sternum. The incision goes down the midline of the sternum to its juncture with the seventh rib. From this point the incision is continued outward over the seventh rib to a point about 6 inches (15.24 cm.) from the sternum. The skin, fat and pectoralis major muscle are dissected up in one flap and the same reflected outward so as to freely expose the cartilages of the third, fourth, fifth and sixth ribs. These cartilages are removed so as to leave the bed of the perichondrium. It is usually best to remove about 1 inch (2.5 cm.) of the fourth, fifth and sixth rib, but leaving behind the posterior periosteum. If the pleura is accidentally opened, a purse string suture of chromic catgut is placed around that opening, the collapsed lung is expanded by the anesthetist, and when the lung has returned to its full capacity, the purse string suture is tightened. If after the removal of these bony and cartilaginous tissues there still remains any point at which the cardiac tug meets with resistance, then that resisting tissue is removed. Frequently this is found to be the sternum, and the same can be removed safely and easily with rongeur forceps.

Shipley [80] recently performed a Brauer type of operation for the relief of pain due to an aneurysm of the aorta. His patient had immediate relief, but this relief is most likely only temporary.

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80. Shipley, A. M.: Personal communication.

In 1925, Hughson [81] resected the fourth, fifth and sixth costal cartilages in a case of Hodgkin's disease. The mediastinal glands were so greatly enlarged as to give symptoms of cardiac pressure. During the operation, the patient's pulse went as high as 180 per minute, but on releasing the pressure by freeing the adhesions and "boning the chest wall" the pulse became very much slower, and the patient's general condition improved. The patient died from the Hodgkin's disease without developing any further symptoms of cardiac pressure.

In 1930, Whittemore [82] removed the cartilages, opened the pericardium and released some adhesions in a case of extensive cardiac enlargement due to valvular disease. This patient showed improvement for ten days, and then died. No autopsy was obtained Also in 1930 Alexander,[83] lifted up the sternum and the cartilages in a case of depressed fracture, with great improvement in the cardiac symptoms. He reported one case in which the Brauer type of operation gave much relief from the anginoid pain.

In 1901, Preble [84] reported that aneurysm of the aorta is associated with 26 per cent of all cases of pericarditis, which he further stated to be "a very high figure when one recalls the comparative infrequency of aneurysm."

In 1929, Graham [85] did a Brauer type of operation in two cases in which the hearts were so large that they could not "help being embarrassed by confinement within a bony chest wall." Graham stated that the results in both of these cases were excellent. Graham further stated this procedure was first advocated by Alexander Morison of Edinburgh, in 1907.

By leaving the perichondrium and the periosteum, the chances of regeneration of the cartilage and the bone are good, and when this has occurred resistance by the thoracic wall again develops. For this reason, some surgeons have attempted to remove the perichondrium and the periosteum, along with the cartilages and ribs, and by so doing, have greatly increased the chances of perforating the pleura.

In 1927, Head [86] completed some experimental work on dogs which gives great promise of being of much assistance in providing the regeneration of ribs. In these experiments he used: (1) the "silver

81. Hughson, Walter: Personal communication, Nov. 28, 1930.

82. Whittemore, Wyman: Exploration of the Pericardium and Decompression of the Heart, Arch. Surg. **21**:1059 (Dec.) 1930.

83. Alexander, John, in discussion on Beck and Griswold: Arch. Surg. **21**: 1112 (Dec.) 1930.

84. Preble, Robert B.: Etiology of Pericarditis, J. A. M. A. **37**:1510 (Dec. 7) 1901.

85. Graham, E. A.: Ann. Surg. **90**:817 (Nov.) 1929.

86. Head, J. R.: Prevention of Regeneration of the Rib, Arch. Surg. **14**:1909 (June) 1927.

nitrate stick"; (2) 50 per cent solution of silver nitrate; (3) concentrated solution of chromic acid, and (4) Zenker's fluid. He demonstrated that anything that would kill the superficial cambium layer of cells would prevent regeneration of ribs. Of the four agents, he found Zenker's solution the most satisfactory. It is more than possible that if a latent infection is present, Zenker's solution might also help to control the same. While I have had no opportunity to try Zenker's solution in doing the cardiolysis operation, I have had excellent results with it in preventing the regeneration of ribs in operations for pulmonary tuberculosis.

For the avulsion of the phrenic nerve, only procaine hydrochloride is used. After locating the nerve, the patient is placed under the fluoroscope, and the diaphragm on both sides observed. If the phrenic nerve has been correctly located, pinching the same with a clamp will allow the diaphragm to rise several inches. When the patient coughs, the affected side does not synchronize with the opposite half of the diaphragm. After being certain that the phrenic nerve is correctly and definitely located, it can be removed. The Alexander clamp is of much assistance in twisting out this nerve, for the flange prevents the nerve from falling off at the tip.

If the x-ray plate and the fluoroscope demonstrated adhesions between the pericardium and the vertebra, no way has as yet been devised for the liberation of such adhesions.

If it has been determined by the x-rays that the heart is surrounded by a thick nonresisting shell, these two operative procedures will be of no aid in the relief of symptoms. The removal of the thoracic wall (Brauer's operation) can be utilized as the primary step in the operation for the decortification of the heart (Delorme). In fact, if any accident occurs, such as the unexpected finding of pus or the puncture of the pleura, the operation can be halted. After the improvement in the patient's condition the next stage in the operative procedure can be undertaken. Following the removal of the cartilages, it is advantageous to tie the internal mammary vessels at the second interspace close to the sternum.

In the approach to the pericardium, it is well to recall the anatomy of the interpleural space: "the uncovered pericardial triangle of Voinitch-Sianojentzky, or the triangle of safety" (Matas). It is some comfort to recall also that the two pleural reflections surrounding this "triangle of safety" are apt to be adherent to each other due to the previous infection, and that injury to the pleura will not necessarily mean collapse of the lung. Frequently the pleura can be wiped away, as suggested by Cutler, by the use of wet cotton pledgets on the end of a clamp. As a rule, however, those adhesions require sharp and careful dissection.

Every reasonable effort should be made to obtain full exposure of the pericardium before the same is incised. Frequently, it is wise to remove a part of the sternum so that the pericardium on the right side of the heart can be removed, if indicated.

Apparently the section of the sternum as advocated by Duval-Barasty produces too great a shock to be employed as the incision of choice. In 1930, Beck and Griswold [60] suggested the possibility of an incision in the skin through the center of the sternum with two cross arms at each end of this incision. The flaps are then dissected out on each side, and the cartilages removed from both sides of the sternum. This method would allow the sternum to remain undisturbed, and give access to both sides of the pericardium.

Lilienthal [50] used the Duval-Barasty midsternal incision in one of his cases and obtained excellent exposure. He further called attention to the fact that this exposure left the wall of the chest intact.

Churchill [1] expressed the belief that a flexible precordial area was of advantage as the heart is apt to become adherent to the thoracic wall, and it would be better to have the heart fixed to a pliable structure than to a firm one.

Schmieden and Fischer [87] suggested a transpleural route through the pleural cavity when before operation it has been determined necessary to release the scar from the left side of the heart.

In 1910, Heitler [88] demonstrated in experiments on dogs under ether that incision of the pericardium showed great disturbance of the pulse unless the pericardium was first cocainized with a 10 per cent solution. In 1912, D'Agata [89] confirmed the observations of Heitler but showed that a much weaker solution of cocaine was equally as efficacious.

Harrigan [90] reported a case of suppurative pericarditis in which the heart stopped beating just as soon as an incision was made in the pericardium with the liberation of about 1,000 cc. of pus. He concluded that the behavior of the heart was due to the incision of the pericardium, but apparently did not seem to consider the possibility of the effects of the sudden liberation of such a great quantity of fluid. Harrigan concluded his report with this passage: "If this relationship between pericardium and myocardium be definitely established, then it will be necessary to revise the present technique of cardiac surgery."

On the other hand, Capps,[91] in 1927, demonstrated that there was no sensation in the pericardium unless the pleura was involved.

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87. Schmieden, V., and Fischer, H.: Ergebn. d. Chir. u. Orthop. **19**:98, 1926.
88. Heitler, M.: Med. Klin. **6**:1562 (June 19) 1910.
89. D'Agata, G.: Arch. f. klin. Chir. **98**:460 (July 8) 1912.
90. Harrigan, A. H.: Ann. Surg. **57**:367 (March) 1913.
91. Capps, J. A.: Pericardial Pain, Arch. Int. Med. **40**:715 (Nov.) 1927.

Alexander, Macleod and Barker [92] had an excellent opportunity to observe cardiac sensibility in a patient with purulent pericarditis. They concluded:

> When pressure was applied forward against the anterior pericardium and thoracic wall, there was some local and referred pain. . . .Pain was also produced by sweeping the finger around the pericardial cavity, by pinching, pricking and scratching the inner surface of the pericardium. Heat and cold were not identified. . . .Our observations do not justify conclusions as to the nerve paths concerned in the sensations produced.

As the sensibility of the pericardium is not definitely established, it is safer, if possible and practical, to inject into the same procaine hydrochloride. The pericardium is opened just over the left ventricle. if the right ventricle is freed first, a fatal tricuspid insufficiency may develop. This would, perhaps, be due to the fact that the ventricle accustomed to its encasement by the leather-like shell, would become acutely dilated when this restraint is removed. It is always well, however, when these adhesions are found, to cut the same close to the pericardium, and as far away as is possible from the coronary vessels. Reference has already been made to the finding of deposits of calcium and infiltrations.

Most authors, who have released hearts from such leather-like shell, speak of the manner in which the "heart leaps to freedom" or some similar expression. Certainly, in the one case in which I operated, the heart was apparently far more anxious to escape than I was to have it do so. The pericardium should be removed in strips about 2 cm. in width and great care always exercised not to injure the myocardium. A piece of pericardium about 7 by 12 cm. should be removed—at least enough to be certain the heart is free. It is important also to be certain that the adherent pericardium is removed from around the great vessels. This can be best done by removing V-shaped pieces of pericardium with the apex of the V toward the vessels. It is wise to be certain there are no pockets of pus or adhesions on the posterior wall of the heart. This can be ascertained by gently passing the fingers around back of the heart. No attempt should be made to free any adhesion with the finger, but exposure should be obtained and the adhesion cut. Ochsner [93] assisted Schmieden in three cases of decortication of the heart and was much impressed with the marked fibrosis that existed not only of the pericardium but also of the myocardium and the epicardium.

Beck and Griswold [60] produced Pick's syndrome by creating adherent pericarditis with the introduction of surgical solution of chlorinated

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92. Alexander, J.; Macleod, A. G., and Barker, P. S.: Sensibility of the Exposed Human Heart and Pericardium, Arch. Surg. **19**:1470 (Dec.) 1929.

93. Ochsner, Alton, in discussion on Alexander; Macleod, and Barker: Arch. Surg. **19**:1481 (Dec.) 1929.

soda (Dakin's solution) into the pericardium. All the dogs died unless the symptoms were relieved by a partial pericardectomy. They concluded that the symptoms were produced "by interfering with cardiac motion as a tightly fitting glove impairs the free movement of the hand," and not by the adhesions between the pericardium and the heart.

Myer [94] reported a case of purulent pericarditis in which the heart had ceased to pulsate when the pericardium was opened, and the simple manipulation of the heart was all that was necessary to start it.

Parlavecchio [95] found sixteen cases in the literature in which autopsies had revealed congenital absence of the pericardium, and in none of the cases was he able to trace any symptoms that could be attributed to the absence of the pericardium. He also completely removed the pericardium from a series of dogs and rabbits, and apparently there were no ill effects. From these observations, Parlavecchio concluded that the surgeon can feel safe in removing any amount of pericardium as far as the heart is concerned.

Naturally, the question has been raised concerning the recurrence of the adhesions and many various drugs and methods have been tried, both clinically and experimentally. None of these seem to have any great value and most surgeons simply bring the flap of muscle, etc., over the heart. However, Ochsner and Herrmann,[96] in 1929, submitted experimental evidence that a vegetable digestant in the pericardial cavity would prevent the reformation of adhesions. In Schmieden's seven cases, there was no instance in which symptoms could be ascribed to the recurrence of adhesions. Sufficient drainage is provided to insure the prevention of cardiac tamponade. This drainage should be placed at the cardiac apex.

REPORT OF CASE

History (abstract of case 21595, Jefferson Hospital).—A white man, aged 29, was admitted to the hospital on June 5, 1927. The family history was essentially unimportant. The following history was obtained: The patient had had the usual diseases of childhood, and had recovered promptly from each. There was no history of any condition that could be considered "rheumatism," and no history of an indefinite fever. He had had influenza eight years before admission, and had recovered apparently completely in two weeks. He had never had any other acute infections, nor any headaches. The eyes had been normal. He had had an indefinite earache in childhood. The teeth had been in excellent condition, with the exception of an alveolar abscess two years previously which "cleared up" in ten days following drainage. He had not had a sore throat nor any sores in the mouth.

He was subject to occasional colds, about one every winter, which lasted a week, and was accompanied with cough and expectoration of mucus. He had

94. Myer, Willy: Ann. Surg. **73**:506, 1921.

95. Parlavecchio, G.: Deutsche Ztschr. f. Chir. **98**:126 (March) 1909.

96. Ochsner, A., and Herrmann, G. R.: Experimental Surgical Relief of Experimentally Produced Pericardial Adhesions, Arch. Surg. **18**:365 (Jan.) 1929.

had no chronic cough, hemoptysis, night sweats, palpitation, dyspnea and edema, and no pleural or precordial pain. His appetite and digestion had been good. He had never been troubled with nausea, vomiting or abdominal pain. The bowel movements had been regular, once daily, and the stools had never been bloody, tarry or clay-colored. The patient had never been jaundiced, and had never had hemorrhoids. The genito-urinary trace had been normal. The patient said he had never had a venereal disease.

He had been married ten years. His wife and three children (aged 9, 6 and 4 years) were living and well. Two children were born dead at term, one seven years ago and another five days ago. The cause of death was unknown, but the labors were difficult. There had been no miscarriage.

There had been no neuromuscular disorders.

The patient had never had any operations or injuries.

Before his present illness, he drank two cups of coffee daily. He did not use tea or alcohol, but chewed tobacco. He had weighed an average of 190 pounds (86.2 Kg.) his best weight being 196 pounds (89 Kg.). He thought that he had lost 20 pounds (9 Kg.) in the past three months.

Present Illness.—The patient was in excellent health up to three months before admission to the hospital or about February 1. At that time he was suddenly taken sick with severe cold, cough, fever and some chills, pains in the joints and general malaise. This was diagnosed influenza and he went to bed for a week. At the end of this time there was still some cough (but no expectoration). He felt much better, so got up and went to work. After another week the same symptoms recurred, but were somewhat worse than before; this time he remained in bed about ten days. Following this attack he was up for a week; then about the middle of March a severe earache developed in the left ear, which lasted eight days. He continued to feel weak and to have some cough until about four weeks previously, when on stooping over he suddenly felt a severe cutting pain and choking sensation in the retrosternal region. He said that it felt as though he would burst. At first the pain occurred only on stooping over, but later it would occur when he was in a recumbent posture, disappearing, however, after a few minutes rest. Soon after the onset of the choking, he saw a physician who gave him some medicine (digitalis), which he believed did him considerable good. He stayed in bed two weeks, at the end of which time the choking had entirely disappeared. At the time of admission he had fever, an occasional cough and marked weakness, but in general, he felt much better than he did two weeks earlier. There was a little expectoration of mucus, but he had noticed no blood at any time.

Examination.—The temperature was 101 F.; pulse rate, 96; respiratory rate, 22, and blood pressure, 118 systolic and 80 diastolic. The patient was a very well developed and fairly well nourished man who showed some loss of weight. He did not complain of any pain, and there was no cough or respiratory distress.

Skeletal examination gave negative results. There was no local or general glandular enlargement. The epitrochlear glands were not felt. The patient's face was somewhat flushed. The lips were a little pale, the nail-beds of good color, and there was no jaundice or cyanosis.

There was no tenderness of the sinuses. The sclerae were a little injected.

The pupils were equal and regular, reacted to light and contracted during accommodation. The ears were normal. The septum was intact and there was no nasal obstruction. The mouth was very dirty. The tongue was coated, and the breath had a bad odor. The tonsils were large and inflamed. The trachea was

slightly deviated to the right. There was no tracheal tug. The thyroid was not enlarged. The thorax was well developed and symmetrical. Expansion seemed a little greater on the right side.

On examining the lungs the percussion note was resonant on the right; on the left it was resonant posteriorly and at the apex anteriorly. Below the second rib and extending into the axilla was a large area of dulness continuous with the area of cardiac dulness. Vocal fremitus seemed normal. Breath sounds were vesicular throughout, but somewhat diminished over the dull area. After the patient coughed a few medium moist râles were heard just medial to the angle of the left scapula. The whispered and spoken voice was normal; there was no pectoriloquy.

Examination of the heart revealed that the point of maximal influence was just inside the nipple line in the fifth interspace. The apex was not well localized. There was no heave. There was no enlargement to the right, and no increase in the retromanubrial dulness. The left border of the heart was continuous with the dull area extending into the axilla. Sounds were faint. The heart rate was rapid but regular. No murmurs were heard.

The abdomen was soft, and no mass was felt. The edge of the liver was 5 cm. below the costal margin. The spleen was not felt, nor was any tenderness elicited.

The extremities were normal. The reflexes were equal and active.

Fluoroscopic examinations showed weak cardiac pulsations. The bases of both lungs were so filled with fluid as to prevent definitely outlining the diaphragm on either side. The position of the heart did not change with change of position of the patient, nor with either forced inspiration or forced expiration. No calcification of the pericardium was seen.

The blood was practically normal. Both Wassermann and Kahn reactions were negative. There was 50 mg. of nonprotein nitrogen per hundred cubic centimeters.

Course.—On June 14, 1927, 225 cc. of bloody fluid was aspirated from the pericardial cavity. Microscopic examination showed numerous red cells, "mainly crenated and otherwise deformed," and a few leukocytes. Guinea-pigs that received injections of the fluid gave negative results.

Between Feb. 1, 1927, and Nov. 30, 1927, the patient's pleural cavity was tapped by various physicians between eighty and ninety times. The largest amount of fluid removed at any one time was about 2,000 cc. The fluid removed from the pleural cavity was always of a clear amber color. Numerous specimens were examined in this hospital, but tubercle bacilli were never found. Inoculations into guinea-pigs gave negative results on five occasions—on four occasions when fluid from the pleural cavity was used and on one occasion when fluid from the pericardial cavity was used. The same type of fluid was also removed from the abdomen on several occasions (the patient was indefinite concerning the exact time and number). After one of these tappings, the spleen was easily palpated.

Operation (November 30).—Ethylene anesthesia by the closed method was started at 10:15 a. m. and discontinued at 10:50 a. m. At the beginning of the operation, the pulse was ranging between 130 and 140 per minute. The blood pressure was taken every five minutes for two hours. Cartilaginous portions of the third, fourth, fifth, sixth and seventh ribs were removed with about an inch of the fourth, fifth and sixth ribs. In dissecting the pleura, a small opening was made in same by accident. A large quantity of amber colored fluid escaped from the pleura. After all fluid was removed, a purse string suture of chromic catgut was placed around the opening, and the lung expanded from the rebreathing bag, while the

purse string suture was tightened. There was no interference with respirations. About half of the sternum was removed with rongeurs and bone forceps. There were numerous adhesions between the pericardium, the thoracic wall and the diaphragm. Those between the pericardium and the wall of the chest were cut. At this stage of the operation, the pericardium came into easy reach. The thickened pericardium was opened at the apex over the left ventricle. The pericardium was about 1 cm. in thickness and very much resembled leather. There was practically no fluid in the pericardial cavity. Scissors were employed to enlarge the opening. As the opening was being enlarged, the heart began apparently to try to force its way out of the thick shell. Then a strip of pericardium about 2 by 7 cm. was removed. At this juncture, the heart was seen to be held at the apex by a strong band of adhesions. This was cut and did not bleed. After the cutting of this adhesion, it was easy to pass the finger around the ventricles. With great care, and with much fear, pieces of pericardium were removed from over the auricles and great vessels. These pieces of pericardium were "V" shaped and had the apex of the "V" toward the vessels. The walls of the coronary vessels looked very thin and care was taken not to disturb them. With the release of the heart, there was an almost instantaneous decrease in the pulse rate and an increase in the blood pressure. Before the patient left the operating room he expressed the greatest relief because he said he could feel that his "heart was free."

On his return to his room, relief and progressive improvement continued. His blood pressure and pulse rate continued in their improved condition. An electrocardiographic study was not made, because it was thought best to wait until he was well enough to go to the electrocardiographic room. He died suddenly on the seventh day after operation. Autopsy showed the heart free in the pericardial cavity. Sections of the myocardium showed many degenerative changes. Sections of the pericardium showed tuberculosis.

SUMMARY

1. The multiplicity of terms describing different operative procedures causes confusion.

2. A historical review and the results of the various operations in the literature up to 1930 are given.

3. As a postmortem observation, the condition has been recognized for many years.

4. Congenital defects of the pericardium have been found in sixty-four cases in which there was no history of any symptoms attributable to such defects.

5. Adherent pericarditis is found in about 4 per cent of routine necropsies.

6. "Acute rheumatic fever" of childhood is the chief etiologic factor, though tuberculosis and other organisms are frequently found to be the cause.

7. Six cases of primary tuberculous pericarditis have been reported in the literature since 1900.

8. There are ninety-six cases of calcareous pericarditis reported in the literature, and it is probable that such is the result of a tuberculous invasion.

9. The condition is far more frequent than it is usually thought to be.

10. Diagnosis is extremely difficult; careful history, physical examination, roentgenograms and electrocardiographs are of great aid.

11. Results of operations justify the plea for more frequent resort to surgical measures in spite of the difficulty of diagnosis.

12. Avulsion of the left phrenic nerve is advocated to supplement the Brauer operation, when the trouble is shown to be due to adhesions between the pericardium and the diaphragm.

13. A description of both the Delorme and Brauer operations is given.

14. A case is reported in which the Delorme operation was done; the patient died on the seventh day after operation.

NOTE.—Since this paper was submitted for publication, one additional case in which operation has been done for decortication of the heart has been located. My attention was called to this article by Dr. R. L. Payne of Norfolk.

The title of the article explains why this case was overlooked: "Sensibility of the Heart; A Human Experience," by George Waugh, William Willcox and Felix Rood. This article appeared in the *Lancet* **2**:1054 (Nov. 21) 1925. The patient was 21 years old; the operation a remarkable success, and the patient in excellent condition five years after operation. The operation was done with local anesthesia (procaine hydrochloride and epinephrine), and the authors were much impressed with the lack of pain except with traction, on the pericardium. They compared their observation concerning the insensibility of the heart to the observations of Lennander (Uppsala) and Baker (London) concerning abdominal viscera which were made about twenty-five years previously.

Dr. Lawson and Dr. Gardner of Roanoke assisted in preparing the paragraphs concerning the electrocardiographic studies, and Dr. Peterson of Roanoke assisted in the preparation of references concerning the use of roentgenograms in the diagnosis of adherent pericarditis.

A RARE CONGENITAL DEFICIENCY OF THE PERICARDIUM *

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The specimen presented is that of a very rare anomaly, showing congenital absence of a separate pericardial sac, the heart being contained in the same serous cavity as the left lung. It was obtained by Dr. W. A. Burr, who was called to the city morgue to undertake the postmortem examination of a middle-aged man who had died suddenly. When the thorax was opened, Dr. Burr was surprised to find the heart and the left lung occupying a common cavity. As he realized the rarity and value of what he had found, he removed all the thoracic viscera, the diaphragm and what remained of the pleural sacs en masse and presented the specimen to the department of anatomy of the University of Toronto.

REPORT OF CASE

The man from whom these viscera were obtained was aged 52, of medium height and well developed. He was unmarried and lived alone and not much was known of his habits. The night of his death he was visiting a friend. As he felt unwell he arose to go into another room and dropped dead. From his friend it was learned that for about one year previous to his death he had suffered occasionally from attacks of weakness. He had led a normal, active life, and, except during the last year, he had not complained of any weakness or disability and had been regularly employed in fairly heavy work. Lately his occupation had been that of operator of a machine in a box factory.

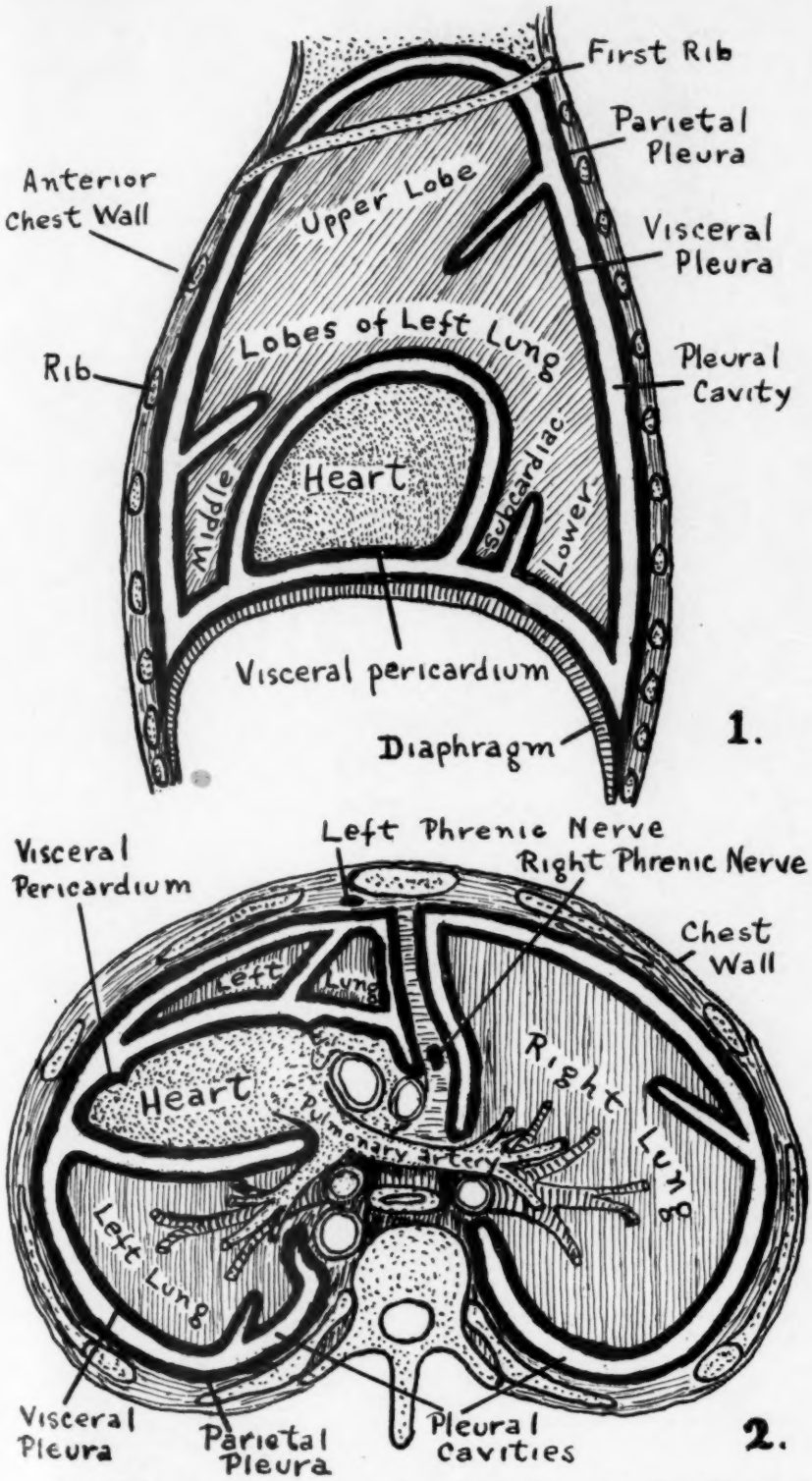
The cause of death found at postmortem examination was thrombosis of the anterior descending branch of the left coronary artery with an accompanying area of soft, degenerated, ventricular muscle.

The specimen, when brought to the laboratory, was placed in a diluted solution of formaldehyde, U. S. P. (1:10) for hardening and preservation. In one mass were the thoracic contents: heart and great vessels, trachea, esophagus, both lungs and the diaphragm, nerves, vessels, glands and parts of both pleural sacs. Each of the latter had been fully opened anteriorly, and most of the costal pleura was lacking.

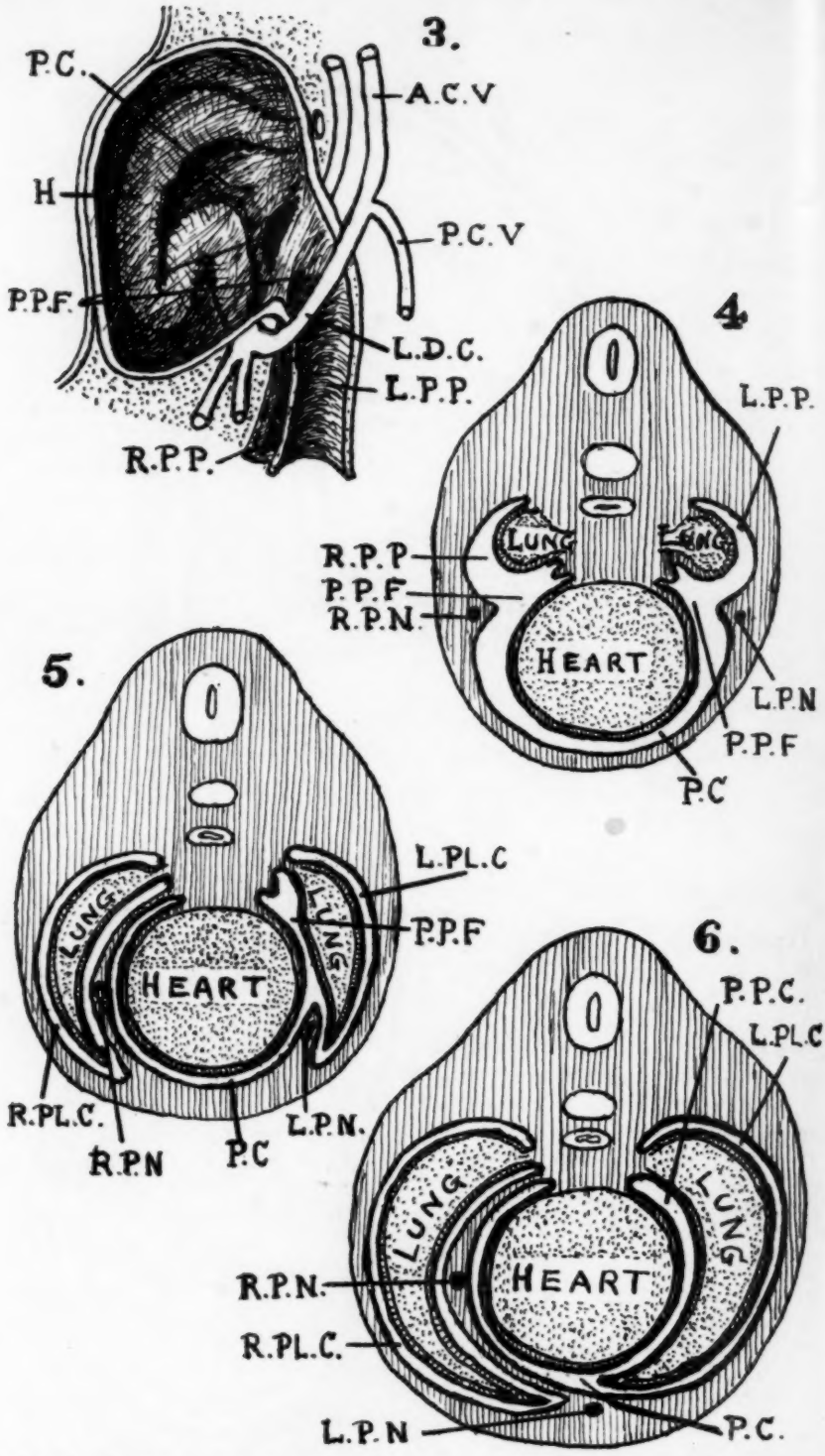
After preservation was completed, photographs of the viscera were taken from various aspects (figs. 7 to 10), and the specimen was then thoroughly studied.

The heart was of moderate size, being somewhat longer than usual (fig. 8), and had a sharp pointed apex. The organ was shaped like a long, narrow cone, and was placed much more horizontally in the thorax than is usual. It lay

* Submitted for publication, Feb. 24, 1931.



Figs. 1 and 2.—*1*, diagram of a sagittal section through the left side of the thorax to show the heart and the left lung occupying a common visceral cavity. *2*, diagram of a transverse section through the thorax at the level of the root of the lung to show the heart and the left lung occupying the same common visceral cavity. Note the reflection of the serous membrane over the various organs and also the position of the left phrenic nerve. The lung lying in front of the heart joins the remainder of the organ just above the level of this section.



Figs. 3 to 6.—*3*, diagram of the pericardial celom and its connection with the pleuroperitoneal passages in a young human embryo. The lung invaginates the pleuroperitoneal passage just below the duct of Cuvier. *4*, *5* and *6*, diagrams of transverse sections of embryos, designed to show successive stages in the failure of the pleuropericardial foramen to close on the left side, thus producing the anomaly described in this paper. *4*, appearance of the lung bud; the pleuropericardial foramen is open on both sides. *5*, the lung growing forward at the side of the heart; the pleuropericardial foramen closed on the right and is still open on the left side. *6*, the lung now surrounds the heart, the left pleuropericardial foramen is still open and fully dilated, the lung and the heart occupying one common cavity, with the left phrenic nerve pushed forward to the anterior wall of the chest. *A.C.V.* indicates the anterior cardinal vein; *H*, the heart; *L.D.C.*, the left duct of Cuvier; *L.PL.C.*, the left pleural cavity; *L.P.N.*, the left phrenic nerve; *L.P.P.*, the left pleuroperitoneal passage; *P.C.*, the pericardial cavity; *P.C.V.*, the posterior cardinal vein; *P.P.F.*, the pleuropericardial foramen; *R.PL.C.*, the right pleural cavity; *R.P.N.*, the right phrenic nerve; *R.P.P.*, the right pleuroperitoneal passage.

right on the diaphragm and extended directly out to the left, and it was so overlapped by the left lung (fig. 7) that only the right atrium and the apex were visible. The apex came to the surface far out to the left between two lobes of the lung. Just medial to the apex was a deep notch (fig. 9) between the right and left ventricles, so that the apex region appeared almost bifid.

There was no fold or partition (fig. 8) to indicate division of the serous cavity in which the heart and left lung were placed. The heart and the left lung possessed smooth, shining, serous surfaces free from adhesions, and one large

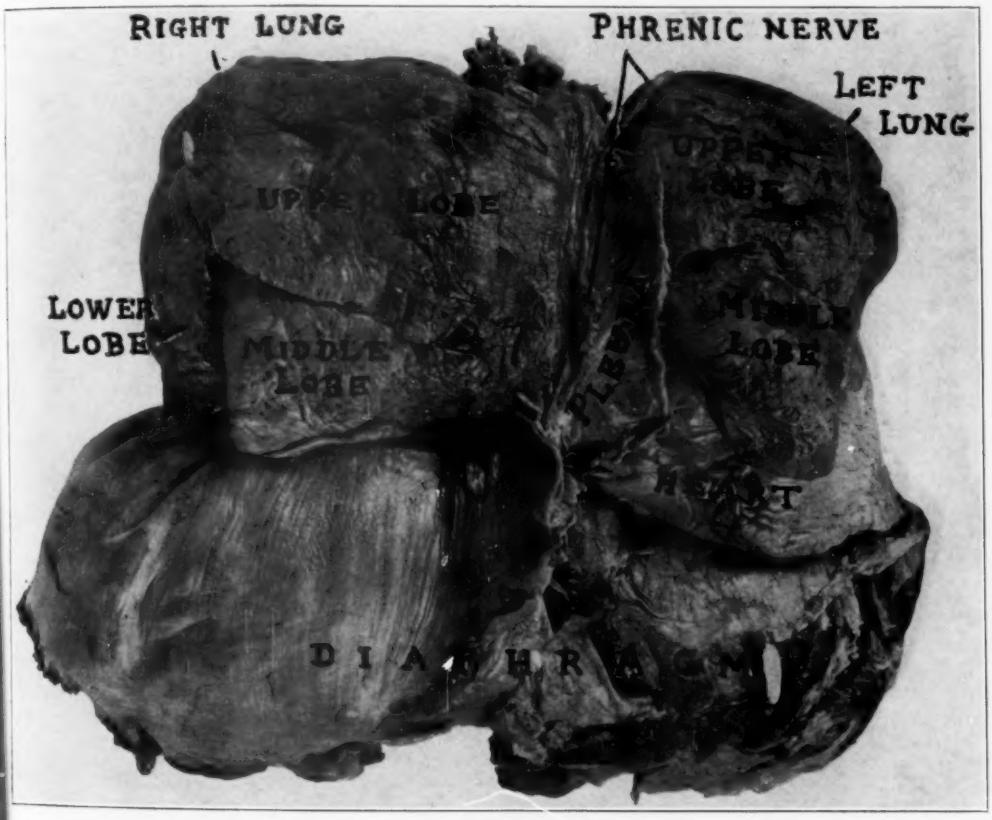


Fig. 7.—Anterior view of the specimen, showing the thoracic viscera and the diaphragm. The pleural cavities have been opened. The heart was more covered in front by the left lung, when in the body, than is shown here. The lungs have become flattened and the apex on each side rounded during preservation.

parietal serous covering on the wall of the chest (fig. 1) was continuous with the visceral surfaces, completing the cavity containing both organs. Owing to the fact that most of the heart was hidden by the overlying lung, one is naturally inclined to call this a pleural cavity at first sight. The cavity, as will be shown later, was developmentally a combined pericardial and pleural one, or a pleuropericardium.

The visceral pericardium invested the heart as usual and was reflected off this organ at the entrance or exit of the great vessels. Behind the aorta and pulmonary artery was the usual tunnel-like passage from side to side known as the transverse sinus (figs. 8 and 10), which had the great veins behind it. In this case, the sinus was situated with its axis running down to the right, owing to the fact that the heart was turned so much more than normally into the horizontal plane to the left.

The oblique sinus of the pericardium (figs. 9 and 10) was also found behind the heart, opening to the left. This sinus, which is bounded by the reflection of

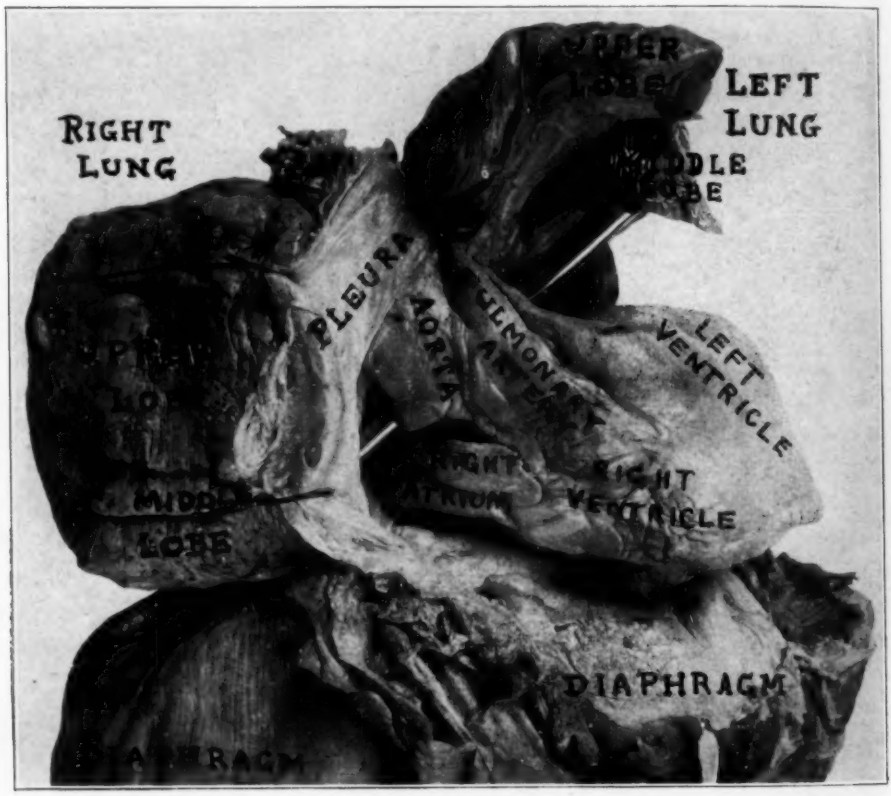


Fig. 8.—Anterior view—the upper part of the left lung has been lifted to expose the heart. The anterior part of the left pleura has been drawn over to the right. The metal rod passes through the sinus transversus.

pericardium off the heart at the entrance of the great veins, usually has a wide opening inferiorly and to the left. In this case, however, the opening was quite narrow, admitting only one finger, but the sinus broadened out somewhat in its interior.

From the anterior surface of the left pulmonary artery and veins, the pericardium turned directly to the root of the left lung (figs. 2 and 10) to form the visceral pleura. Behind the root, the pleura was continuous from the bronchus and vessels with the wall of the sac. Below the root of the lung, a thin reflection

of serous membrane (figs. 9 and 10) was continued off the heart as far down as the surface of the left ventricle posteriorly, and also a small area of the diaphragm on to the medial surface of the lung below the root. This fold was interpreted as the lateral ligament of the lung. It was responsible for narrowing the entrance into the oblique sinus by extending for some distance below the left pulmonary veins.

The parietal part of this serous sac was applied to the side of the vertebrae, the inner surface of the ribs and the back of the sternum. At the midline behind the sternum it turned dorsally (figs. 2, 7 and 8) and passed back toward the

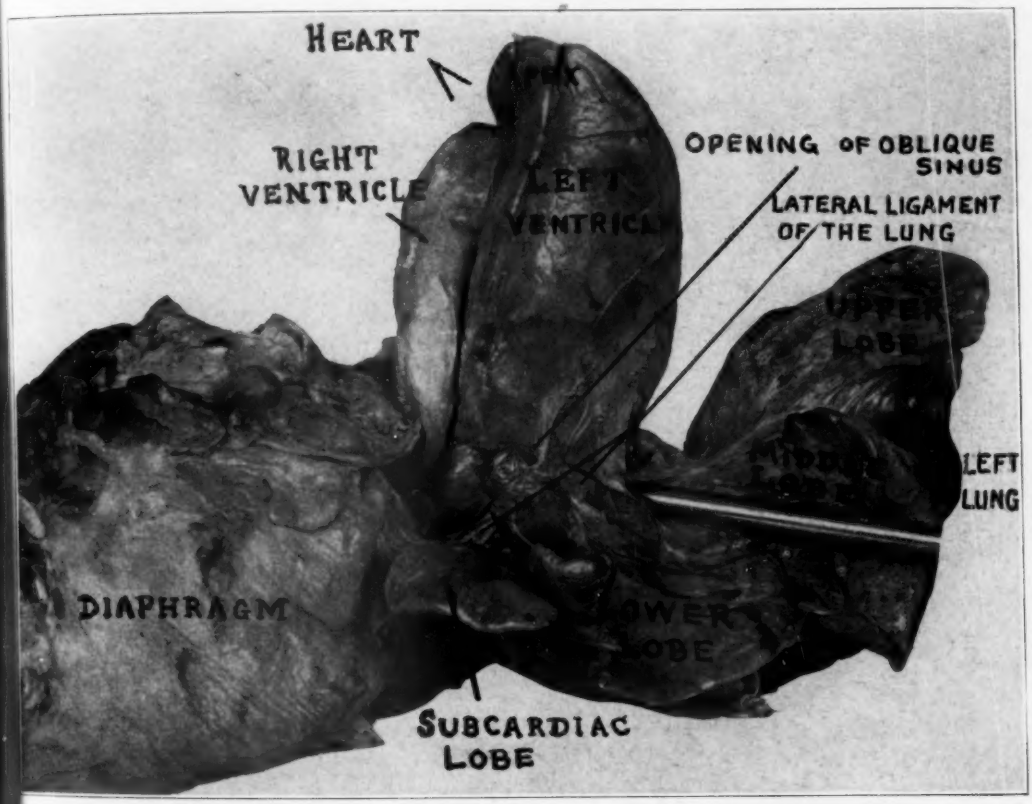


Fig. 9.—View from the left and somewhat inferiorly. The left lung has been drawn away from the heart, and the heart has been elevated so as to show its postero-inferior portion. The metal rod runs into the sinus transversus.

heart, lying in direct contact with the corresponding portion of the right pleura. The diaphragm was covered on its upper surface right up to the midline, where the right and left pleurae, in contact with each other, were reflected to form the mediastinal portion. The cervical dome was normally placed. The right pleura showed a normal disposition.

The left lung was most interesting in its arrangement. Fissures passing right into the hilus cut it into four distinct lobes, of which the upper two lay above and in front of the heart (figs. 1 and 7) and the lower two (figs. 1, 9 and 10)

behind the heart. These four were named the upper, middle, lower and subcardiac lobes. The upper and middle lobes corresponded with the upper lobe usually seen on the left side, the fissure between them corresponding with the intermediate fissure normally found on the right side, and sometimes on the left, separating the normal middle lobe from the upper lobe.

The lobe called the subcardiac was separated by a deep fissure from the lower lobe, in relation to which it lay posteromedially, and was in contact with the

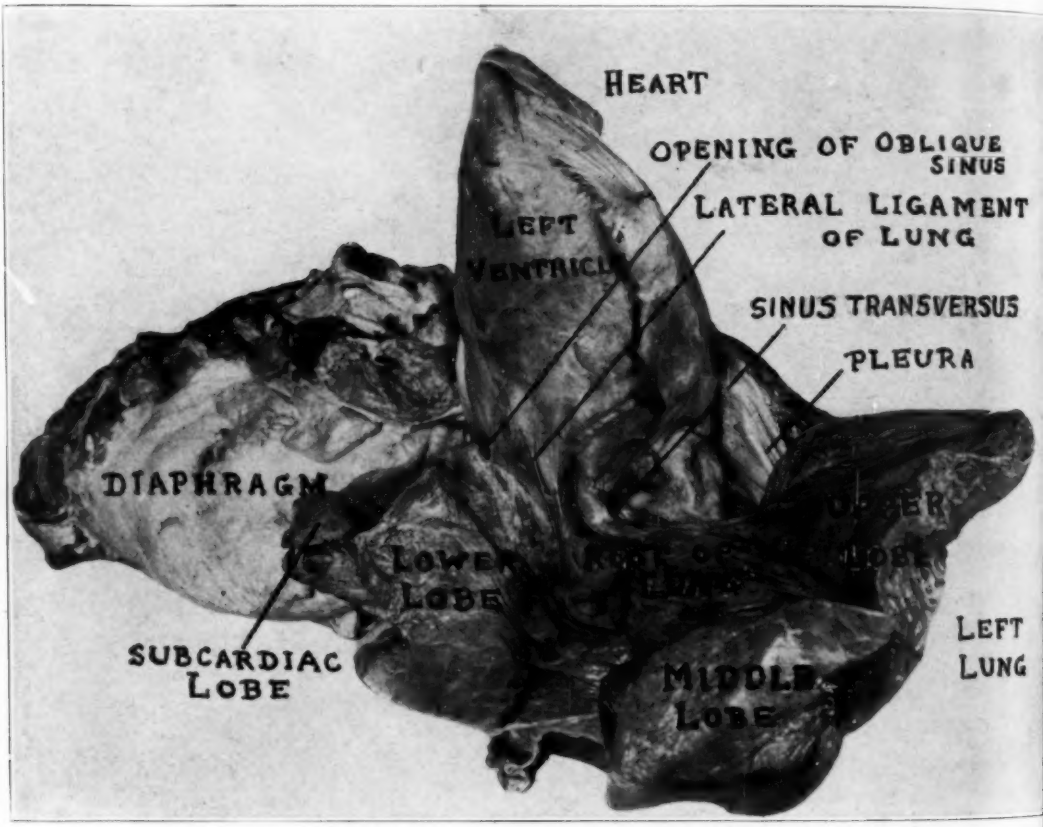


Fig. 10.—View from the left and somewhat superiorly. The left lung has been drawn away from the heart, and the heart has been elevated.

curved posterior surface of the heart. The lower edge of this lobe therefore insinuated itself slightly between the heart and the diaphragm.

The right lung, which was larger than the left, was divided into the usual three lobes, upper, middle and lower.

The right and the left vagus nerves were normal in position and arrangement. As they passed behind the roots of the lungs and on the esophagus, a disturbance of their course was not to be expected.

The right phrenic nerve (fig. 2) also followed the usual course, lying in front of the root of the right lung, and then passing down over the right side of the

heart in the connective tissue between the mediastinal walls of the right pleura and the left pleura (or pleuropericardium).

The left phrenic nerve (figs. 2 and 7) was greatly displaced, for instead of lying in the mediastinum it had been forced out into contact with the wall of the chest and was lying outside the parietal pleura against the deep surface of the sternum.

COMMENT

The condition just described is extremely rare, and all cases except one or two have been found in human beings; the others were found in dogs.

Moore reviewed the literature to 1925; including the case described by him, there were sixty-four cases on record at this time. He stated that the first case of absence of the pericardium to be reported was described by Realdus Columbus in 1559, but it was not believed until a second case was reported by Baillie in 1788. In 1874, there were ten cases; in 1910, there were thirty-two cases on record, and in 1925, they totalled sixty-four. One additional case was reported by Grant in 1927, and my case now makes the sixty-sixth.

Moore classified forty-two cases, which were well described, as follows:

Group 1: Heart and left lung in one serous cavity, 59.5 per cent.

A. With complete absence of separate pericardium.

B. With rudimentary folds or other evidence of partly separate pericardium.

Group 2: Heart occupying a pericardial cavity that had a foramen into the left pleural cavity, 21.4 per cent.

Group 3: Heart lying between the right and the left closed pleural cavities, in connective tissue, without a pericardium or only a rudiment at the base of the heart, 19.1 per cent.

Several cases in the last group showed undoubted evidence of being produced by an obliterative adhesive pericarditis. The present case would be classed under group 1*A*.

The production of the anomaly in the cases in which there is a serous cavity has been explained by various authors (see Moore) in several ways, but it seems to me that there should be no doubt in the matter, as it can be explained naturally on purely embryologic grounds.

It will be remembered that at a certain stage of development (figs. 3 and 4) there is a well marked pericardial cavity still connected by a pleuropericardial foramen on each side to the corresponding pleural cavity. At about the same level, each pleural cavity is also connected by the pleuroperitoneal passage to the peritoneal cavity.

On its way to the heart, the duct of Cuvier runs in a fold which lies lateral to the pleuroperitoneal passage, and from the fold a partition grows ventrally to close the pleuropericardial foramen, while another one grows dorsally to close the pleuroperitoneal passage. The failure of the ventral partition to appear would leave the communication between the

pericardial and pleural cavities open (fig. 5). If the defect were of sufficient size, part of the heart could protrude through this opening and would lie in the pleural cavity, giving rise to the cases classified as showing a partly absent pericardium.

If the heart remained in its cavity and part of the lung growing ventrally insinuated itself into the pleuropericardial foramen and forced its anterior margin forward ahead of it, the foramen would be dilated gradually until the surfaces of the pleura and pericardium would have no fold or division between them and the two cavities would be fully opened up into one large combined cavity (fig. 6) holding both the heart and the left lung, as seen in the case reported.

The phrenic nerve lies in the connective tissue between the pericardial and pleural membranes, in the anterior border of the foramen between the two cavities, so that on dilatation of the foramen the nerve is carried forward. If the dilatation is complete, as it was in the case described, the nerve is finally forced sufficiently forward to be in contact with the deep surface of the anterior wall of the chest (figs. 2, 6 and 7), which is the position in which the nerve was found in this specimen.

In only one instance is there a record of the opening persisting between the pericardium and the right pleural cavity, and this was in the case of the dog described by Moore. The almost universal occurrence of this anomaly on the left side is associated with the early disappearance of the left superior vena cava. If this occurs too early, it can easily be conceived that it may interfere with the closure of the opening alongside of which it lies. The failure of closure on the right side in one case, however, shows that even the continued presence of the vein will not absolutely guarantee the appearance and development of the normal partition that closes the aperture. Once the opening fails to close, the presence of either the heart or a lung in it will enlarge it greatly and expand it so that the two cavities become more or less completely one.

In reference to age, the cases reported show the widest variations as this anomaly has been found not only in fetuses but in many adults. In twenty cases in which exact clinical knowledge as to the condition of the heart was obtainable (tabulated by Grant), the youngest patient was 20, and the oldest 62 years of age. The anomaly is thus not incompatible even with the attainment of old age.

The records also show that the lack of a separate pericardium does not necessarily make the person so affected weak or debilitated, for many of these persons showed robust good health and participated in strenuous activity. The patients whose cases were listed were soldiers, masons, laborers and office workers. The man whose case is the subject of this paper was active and hard working, and he reached the age of 52.

Sex does not seem to have a bearing on the production of the anomaly, which was exhibited by members of both sexes of various ages.

The causes of death were not always cited for the different cases, but when noted they often had no reference to any special condition of the heart and consisted of such diseases as syphilis, nephritis, pneumonia and carcinoma.

Enlargement of the heart was present in ten of the twenty most accurately recorded cases, but not all of the patients died of heart failure; it was not present in the other ten cases. Thus, even with absence of a separate pericardial sac to support the heart it is not essential for a person living an active life to have hypertrophy to possess a heart strong enough to support him. The heart was not enlarged in the case forming the subject of this paper.

In view of its character as a serous membrane, the pericardium acts as a bursa to the heart and provides a free and almost frictionless surface for its movements. However, owing to the strong fibrous layer in the parietal pericardium, it has long been believed and widely taught that the pericardium exerts a supporting and restraining influence on the heart, preventing undue dilatation in times of sudden strain. Of course, long-continued or steadily applied strains will dilate the pericardium, and the supporting action is done away with under such conditions, for it acts to advantage only under stresses of short duration. Thus it is that the pericardium does not prevent the dilatation of a heart the myocardium of which is weakening.

Hauffe expressed the belief that during systole, or contraction, of a cardiac chamber, the wall of the heart tends to be withdrawn from the parietal pericardium. This creates a negative pressure in the pericardial cavity, which helps the diastole or expansion of the filling chamber, as it tends to expand this chamber and suck blood into it. In this way, he looked on the heart and pericardium as a combined force and suction pump.

In the series of cases recorded with absence of the pericardium, there were many persons who lived active lives entailing considerable physical exertion; they did not show signs of cardiac weakness, nor did they have hearts larger than normal. In these cases the heart was in the same cavity as the left lung. The lung could not replace the pericardium either in its function as a restraining influence on dilatation or as something to provide suction to help dilate the chambers in each diastole, for the lung is too yielding and lacking in resistance. Both of these functions would be interfered with in such cases, as the lung would yield and neutralize any change of pressure that was created.

Therefore, it follows that a separate pericardium is not an essential part of the mechanism of the heart. It serves primarily neither for support of the heart nor to provide aid in keeping up the circulation, but acts

primarily as a serous membrane the important function of which is to provide a practically frictionless bursa that will facilitate the movements of the heart. This function can also be accomplished quite well with the heart in the pleural cavity.

CONCLUSIONS

A specimen is described taken from a man, aged 52, who exhibited a rare congenital anomaly in which the heart and the left lung occupied a common serous cavity.

This common cavity was produced in embryonic development by a combining of the pericardial and the left pleural cavities, through failure of the left pleuropericardial foramen to close, followed by its subsequent dilatation.

The left lung exhibited four lobes.

The left phrenic nerve lay in contact with the deep surface of the anterior wall of the chest.

The failure of the pleuropericardial foramen to close was probably associated with the changes accompanying the disappearance of the left superior vena cava.

This is the sixty-sixth case of its kind recorded in 371 years.

This condition is not incompatible with a long, active life, free from any special weakness of the heart.

A separate pericardium is not absolutely essential to the normal functioning of the heart.

The main function of the pericardium is to provide a nearly frictionless serous sac to facilitate the movement of the heart.

BIBLIOGRAPHY

An extensive bibliography has not been appended, but the interested reader will find a list of forty-four references in Grant's paper and twenty-nine references in Moore's article. Standard textbooks on anatomy and embryology will supply accounts of the normal structure and development of the pericardium.

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Moore, R. L.: Congenital Deficiency of the Pericardium, Arch. Surg. **11**:765 (Nov.) 1925.

The following article was published after this paper was submitted for publication, adding one extra case to those cited.

Beck, C. S.: Congenital Deficiency of the Pericardium, Arch. Surg. **22**:282 (Feb.) 1931.

METAPHEN AS A DISINFECTANT OF THE SKIN*

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AND
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During the past year Raiziss, Severac and Moetsch [1] reported that solutions of metaphen, applied on gauze for five minutes in strengths ranging from 1:500 to 1:2,500, produced complete sterilization of the skin of rabbits contaminated with broth cultures of *Staphylococcus aureus, Streptococcus hemolyticus* and *Bacillus subtilis* after preliminary cleansing. White and Hill,[2] however, questioned the results on the basis that the drug was transferred from the skin to the subcultures in amounts sufficient to inhibit bacterial growth in the medium, thereby leading to the erroneous supposition that metaphen had completely sterilized the skin. Since they stated that metaphen in the dilution 1:500 cannot be relied on regularly to sterilize normal human skin after an exposure of five minutes, and since the subject of disinfection of the skin is one of great practical importance, especially in relation to surgery, we have thought it advisable to repeat the experiments of these workers in order to determine the possible sources of discrepancy in their reports and in an effort to fix the exact status of metaphen as a disinfectant of the skin.

Our experiments with rabbits were conducted as described by Raiziss, Severac and Moetsch. The hair of the abdomen was removed with a weak solution of barium sulphide, followed by a cleansing of the skin with soap and water and the application of metaphen in the dilution 1:1,000 for five minutes, followed by the administration of alcohol and ether. The skin was then contaminated with a mixture of equal parts of broth cultures of *Staphylococcus aureus, Streptococcus hemolyticus* and *B. subtilis* and allowed to dry. Cultures were invariably positive, indicating the presence of viable organisms.

Sterile gauze was then saturated with metaphen in the dilutions 1:500 and 1:2,500 and applied for five minutes, and cultures were made by rubbing the areas for thirty seconds with sterile swabs moist-

* Submitted for publication, Feb. 28, 1931.
* From the Research Institute of Cutaneous Medicine.

1. Raiziss, G. W.; Severac, Marie, and Moetsch, J. C.: Metaphen as a Germicide and Skin Disinfectant, J. A. M. A. **94**:1199 (April 19) 1930.

2. White, E. C., and Hill, J. H.: Inefficiency of Metaphen as a Skin Disinfectant, J. A. M. A. **95**:27 (July 5) 1930.

ened with sterile broth. The tip of each swab was then clipped and dropped into bouillon.

As stated, White and Hill contended that the swabs may carry enough metaphen into tubes containing 10 cc. of broth to prevent bacterial growth. If this were true, it is likely that cultures of the skin with moistened swabs held horizontally would pick up and transfer more metaphen than swabs held vertically. Therefore, we cultured the skin in both ways by rubbing for thirty seconds and inoculated not only tubes carrying 10 cc. of broth, but likewise flasks carrying 100 and 900 cc., the latter as employed by White and Hill, to dilute any metaphen carried over on the swabs beyond the bacteriostatic threshold.

All of our subcultures into tubes containing 10 and 100 cc. of broth were sterile, while some in 900 cc. gave growths. Off-hand this would indicate that the swabs had transferred bacteriostatic amounts of metaphen to the tubes containing 10 and 100 cc. of broth, but when these were inoculated with 4 mm. loopfuls of a twenty-four hour broth culture of *Staphylococcus aureus* at the end of seventy-two hours, all gave heavy growths.

At the same time, we applied metaphen in the dilutions 1 : 500 and 1 : 2,500 on squares of gauze to the skin of the under surface of the forearm of two laboratory workers, as described by White and Hill; five minutes later we rubbed the wet areas for fifteen seconds with swabs held vertically and horizontally and then clipped these with sterile scissors into tubes containing 10, 100 and 900 cc. of broth. Again the cultures 10 and 100 cc. showed no growth, while some of those of 900 cc. developed growths of *B. proteus* and *B. subtilis*. However, when the subcultures of 10 and 100 cc. were inoculated with *Staphylococcus aureus* at the end of seventy-two hours, heavy growths of this organism developed. Furthermore, when the 10 and 100 cc. of broth were inoculated with *Staphylococcus aureus* immediately after the cultures were taken from the skin, growth developed as promptly and as heavily as in the controls, without exhibiting any demonstrable degrees of bacteriostatic activity due to metaphen carried over on the swabs.

In this, however, we had a perplexing situation in that our subcultures of 10 and 100 cc. showed no growths and did not exhibit bacteriostasis when inoculated with 4 mm. loopfuls of twenty-four hour broth culture of *Staphylococcus aureus,* while some of the subcultures of the skin in 900 cc. showed heavy growths.

Because of these paradoxical results, we then tested the skins of twenty additional subjects from the laboratory personnel. The forearms were chosen, and preliminary cleansing was not employed. Four thicknesses of sterile gauze (5 by 8 inches [12.7 by 20.32 cm.]) were saturated with metaphen in the dilution 1 : 500 in a pan and were accurately applied to the skin for exactly five minutes as timed with a stop

watch. Cultures were then made of the wet areas with sterile swabs held vertically and whirled about for ten seconds, followed by clipping of the ends with sterile scissors into tubes containing 10 cc. of broth and flasks containing 100 and 900 cc. In each case, two cultures were made into 900 cc. of broth contained in the usual wide-mouthed Erlenmeyer flasks and in the narrow-mouthed volumetric flasks, in order to reduce to a minimum the chances of contamination with air from the opening and closing of the latter. At the end of seventy-two hours of incubation, the subcultures showing no growths were inoculated with 4 mm. loopfuls of twenty-four hour broth culture of *Staphylococcus aureus* as a test for the presence of bacteriostatic amounts of metaphen. All cultures showing "no growths" were kept under observation at 37.5 C. for ten days. The results are summarized in the accompanying table as follows:

1. Cultures were taken from all of the skins with swabs and placed in tubes containing 10 cc. of broth before metaphen was applied. All gave growths of various organisms, including *Staphylococcus albus, B. proteus, B. subtilis, B. pseudodiphtheriae, B. coli* and *Sarcinae.*

2. After the application of metaphen, all of the subcultures in tubes containing 10 cc. of broth were sterile after seventy-two hours of incubation. These were then inoculated with 4 mm. loopfuls of twenty-four hour broth culture of *Staphylococcus aureus,* and all gave good growths.

3. Six, or 30 per cent, of the subcultures in the flasks carrying 100 cc. of broth from the twenty subjects gave growths including *Staphylococcus albus, B. subtilis, B. pseudodiphtheriae* and *Sarcinae.* When the remaining 14, or 70 per cent, sterile cultures were inoculated with *Staphylococcus aureus* at the end of seventy-two hours, all gave good growth.

4. Eight, or 40 per cent, of the subcultures from the twenty subjects gave growths in the wide-mouthed Erlenmeyer flasks containing 900 cc. of broth, including *Staphylococcus albus, B. subtilis, B. pseudodiphtheriae* and *Sarcinae.* When the remaining 12, or 60 per cent, of sterile cultures were inoculated with *Staphylococcus aureus* at the end of seventy-two hours, all gave good growth.

5. Five, or 25 per cent, of the subcultures from the twenty subjects gave growths in the narrow-necked volumetric flasks containing 900 cc. of broth of the same organisms. When the remaining fifteen, or 75 per cent, of the sterile cultures were inoculated with *Staphylococcus aureus* at the end of seventy-two hours, all gave good growths.

The occupations of the subjects tested had some influence on the results, in that those engaged in "dirty" work as laboratory cleaners (nos. 5, 7, 9 and 19) showed heavier growths than the remaining subjects, who were mostly technicians and members of the staff. Indeed,

before the application of metaphen, cultures from two of the latter did not show growths and therefore are not included in the series; however, it was apparent that the number and kinds of bacteria on the skin had some influence on the results, and for this reason tests of these kinds conducted in different laboratories cannot be expected to give more than approximately similar results. Furthermore, it would appear that the

Metaphen in Aqueous Solution as a Disinfectant of the Skin

		Results of Cultures After 1:500 Metaphen for Five Minutes			
No.	Culture of Skin	In 10 Cc. of Broth	In 100 Cc. of Broth	In 900 Cc. of Broth, Erlenmeyer Flask	In 900 Cc. of broth, Volumetric Flask
1	Staphylococcus; B. subtilis	No growth	Staphylococcus	Staphylococcus	No growth
2	Staphylococcus	No growth	No growth	No growth	No growth
3	Staphylococcus; Sarcinae	No growth	No growth	Staphylococcus B.	No growth
4	B. subtilis; B. proteus	No growth	Staphylococcus; Sarcinae	Sarcinae	Sarcinae
5	Staphylococcus; B. subtilis	No growth	Staphylococcus	Staphylococcus	Sarcinae
6	Staphylococcus; Sarcinae	No growth	No growth	No growth	No growth
7	B. pseudodiphth.; Staphylococcus	No growth	No growth	B. pseudodiphth.	B. pseudodiphth.
8	Staphylococcus	No growth	B. pseudodiphth.; B. subtilis	B. subtilis; B. proteus	B. subtilis
9	B. proteus; B. pseudodiphth.	No growth	B. pseudodiphth.; B. subtilis	B. subtilis; B. proteus	B. subtilis
10	Staphylococcus	No growth	No growth	No growth	No growth
11	Staphylococcus	No growth	No growth	No growth	Staphylococcus
12	Staphylococcus; B. pseudodiphth.	No growth	B. pseudodiphth.	No growth	No growth
13	Staphylococcus	No growth	No growth	No growth	No growth
14	Staphylococcus	No growth	No growth	No growth	No growth
15	Staphylococcus; B. proteus	No growth	No growth	Staphylococcus	No growth
16	Staphylococcus	No growth	No growth	No growth	No growth
17	Staphylococcus; B. pseudodiphth.	No growth	No growth	B. pseudodiphth.	No growth
18	Staphylococcus	No growth	No growth	No growth	No growth
19	Staphylococcus; B. coli; B. subtilis	No growth	B. subtilis	No growth	No growth
20	Staphylococcus; B. subtilis	No growth	No growth	No growth	No growth

bacterial flora varies in different localities of the skin even within a small space, or, at least, that the organisms recovered in cultures may vary, probably due in part to their different depths in the skin. For this reason, tests conducted with the skins of rabbits first prepared by scrubbing with soap and water followed by the application of alcohol and ether and contamination with broth cultures of bacteria may be expected to yield more consistent and more favorable results, since most of the bacteria are on the surface of the skin instead of being located at varying depths.

SUMMARY

Owing, therefore, to the variables inseparably associated with tests of these kinds, only broad conclusions are justified. All things considered, it has appeared to us that in the method employed, in which subcultures are made with swabs, at least 100 cc. of broth is required instead of 10 cc. Probably narrow-necked volumetric flasks carrying 900 cc. of broth are most acceptable and suitable for the purpose of still further diluting any disinfectant carried over on the swabs beyond the bacteriostatic threshold and for reducing contamination with air to a minimum, although the large size and the large amounts of medium required constitute technical objections when many tests are to be conducted and when 100 cc. would appear to be sufficient. Dilution, however, is the chief factor since with proper care and technic contamination with air can be largely, if not entirely, prevented. As a matter of fact, we opened a number of flasks in the same manner and for the same period of time as required for making the cultures and in no instance did any of these controls show bacterial growths. The use of large amounts of broth for subculturing is especially required when one is testing such a powerful bactericide as metaphen, which Raiziss and his colleagues found bacteriostatic for *Staphylococcus aureus* in dilutions as high as 1 : 20,400,000.

The results have indicated, therefore, that the 100 per cent "no growths" of subcultures in 10 cc. of broth may have been due in part to the presence of bacteriostatic amounts of metaphen carried over on the swabs, as stated by White and Hill, although we had no direct evidence of this, since all of the cultures seeded seventy-two hours later with *Staphylococcus aureus* yielded good growths. We surmised that some change may have occurred during the seventy-two hours of incubation whereby the bacteriostatic activity of the metaphen was removed, but in separate tests not included in the foregoing the subcultures in 10 cc. of broth were seeded with *Staphylococcus aureus* immediately after subculturing the skin, and all gave good growths. Our conclusion, therefore, is that sufficient metaphen may be carried over on the swabs to inhibit the growth of living but devitalized bacteria from the skin carried over at the same time but insufficient for inhibiting the growth of 4 mm. loopfuls of fresh vital twenty-four hour broth cultures of *Staphylococcus aureus*.

CONCLUSIONS

1. The application of 1 : 500 aqueous solution of metaphen to the skin for five minutes was found to be a highly efficient disinfectant.

2. In confirmation of the report of Raiziss, Severac and Moetsch, the application of 1 : 500 aqueous solution of metaphen for five minutes to the disinfected skin of rabbits secondarily contaminated with broth

cultures of various organisms usually resulted in complete disinfection, probably because the bacteria were on the surface of the skin.

3. The application of 1 : 500 aqueous solution of metaphen to the unprepared skin of human beings for five minutes resulted in complete disinfection in at least from 70 to 75 per cent of persons. In the remaining 25 to 30 per cent, disinfection was incomplete, probably because of a failure of the disinfectant in aqueous solution to reach and destroy organisms located in the depths of the skin in the time allowed. Metaphen solutions in alcohol and acetone were not tested.

4. In 95 per cent of cases, however, the application of 1 : 500 aqueous solution of metaphen to unprepared skins for five minutes resulted in the complete destruction of staphylococci, which are of most importance from the standpoint of disinfection in relation to surgery.

5. The degree of bacterial contamination of the skin influenced the degree of disinfectant activity of aqueous solutions of metaphen.

6. Subcultures of the skin with swabs into 10 cc. of broth, following the application of 1 : 500 aqueous solutions of metaphen, were always positive when inoculated with staphylococci and failed to corroborate the observations of White and Hill in these respects.

7. However, subcultures of the skin with swabs in 10 cc. of broth, following the application of 1 : 500 aqueous solutions of metaphen, apparently transfer sufficient of the compound to prove bacteriostatic for devitalized organisms.

8. Therefore, in tests of the bactericidal activity of metaphen on the skin, subcultures should be made in 100 cc. or larger volumes of broth, as advised by White and Hill.

THE DISCHARGE OF BILE INTO THE DUODENUM

AN EXPERIMENTAL STUDY *

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The mechanism of biliary secretion and flow has been studied extensively for many years, yet some phases of it are not fully understood. This is due in part to the differences of opinion regarding the anatomy of this region and also to the difficulty of securing convincing experimental information without interfering with normal physiologic processes. The liver normally secretes bile continuously, although the rate is variable. The flow from the common bile duct into the duodenum, however, is interrupted. Most anatomic studies have shown the presence of a muscular arrangement at the duodenal end of the choledochus, which could act as a sphincter, and many physiologic experiments and hypotheses concerning a sphincter mechanism of the choledochus have been made. The studies have not all been concordant. The object of the present experimental study was to observe directly the flow of bile into the duodenum in the intact animal and thus attempt to determine the mechanism controlling the discharge of bile. Most previous direct observations of this mechanism have been made as acute experiments on anesthetized animals. Under such circumstances normal physiologic processes are likely to be disturbed. To eliminate such complicating factors, an operative procedure was devised that so exposed the duodenal orifice of the duct as to permit long and varied observations under different physiologic conditions in intact animals. Animals thus prepared remained in a seemingly normal condition for many weeks or months after operation. The anatomic derangement may have made some physiologic changes, for which, of course, allowance must be made. The experiments were concerned only with the direct observation of the duodenal orifice of the duct, its action and the flow of bile from it and with notation of the influences of other normal physiologic processes and of various substances administered orally and subcutaneously and applied locally to the exposed duodenal segment. After the satisfactory termination of these observations, cholecystectomy was performed, and the effects were noted.

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In 1861, Glisson[1] first intimated the existence of a sphincter at the duodenal end of the choledochus. Such a structure in man and in many animals has been carefully studied by Gage,[2] Oddi,[3] Hendrickson,[4] Letulle and Nattan-Larrier,[5] Helly,[6] Rost,[7] Job[8] and others. Doyon[9] and Freeze[10] concluded that the great splanchnic nerves contain the motor fibers to the biliary tract. Contrary to this opinion, Courtade and Guyon,[11] Bainbridge and Dale,[12] Lieb and McWhorter[13] and Mann[14] considered the vagi to be the motor nerves to the biliary passages. A theory of contrary innervation, causing simultaneous contraction of the gallbladder and dilatation of the orifice of the choledochus, has been advanced at various times by Foster[15] and Doyon and

1. Glisson, F., quoted by Oddi, Ruggero: Arch. ital. de biol. **8**:317, 1887.

2. Gage, S. H.: The Ampulla of Vater and the Pancreatic Ducts in the Domestic Cat, Am. Quart. Micro. J. **1**:123 and 169, 1879.

3. Oddi, Ruggero: D'une disposition à sphincter spéciale de l'ouverture du canal cholédoque, Arch. ital. de biol. **8**:317, 1887.

4. Hendrickson, W. F.: A Study of the Musculature of the Entire Extra-Hepatic Biliary System Including that of the Duodenal Portion of the Common Bile Duct and the Sphincter, Bull. Johns Hopkins Hosp. **9**:221 (Sept.-Oct.) 1898.

5. Letulle, Maurice; and Nattan-Larrier: Région vatérienne du duodénum et ampoule de Vater, Bull. Soc. anat. de Paris **73**:491 (June) 1898.

6. Helly, K. K.: Die Schliessmuskulatur an den Mündungen des Gallen- und der Pankreasgänge, Arch. f. mikr. Anat. **54**:614, 1899.

7. Rost, Franz: Die funktionelle Bedeutung der Gallenblase: Experimentelle und anatomische Untersuchungen nach Cholecystektomi, Mitt. a. d. Grenzgeb. d. Med. u. Chir. **26**:710, 1913.

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9. Doyon, M. M.: De l'action exercée par le système nerveux sur l'appareil excréteur de la bile, Arch. de physiol. norm. et path. **6**:19, 1894.

10. Freeze, J. A.: The Force of Contraction of the Gall-Bladder and the Course of Its Motor and Inhibitory Nerve Fibers, Bull. Johns Hopkins Hosp. **16**:235 (June) 1905.

11. Courtade, D., and Guyon, J. F.: Action motrice du pneumogastrique sur la vésicule biliaire, Compt. rend. Soc. de biol. **56**:313 (Feb. 20) 1904; Trajet des nerfs extrinsèques de la vésicule biliare, ibid. **57**:874 (May 28) 1904.

12. Bainbridge, F. A., and Dale, H. H.: The Contractile Mechanism of the Gallbladder and Its Extrinsic Nervous Control, J. Physiol. **33**:138 (Nov. 9) 1905.

13. Lieb, C. C., and McWhorter, J. E.: The Innervation of the Gall-Bladder, Proc. Soc. Exper. Biol. & Med. **12**:102, 1914-1915; Action of Drugs on the Isolated Gallbladder, J. Pharmacol. & Exper. Therap. **7**:83 (July) 1915.

14. Mann, F. C.: A Comparative Study of the Anatomy of the Sphincter at the Duodenal End of the Common Bile-Duct with Special Reference to Species of Animals Without a Gallbladder, Anat. Rec. **18**:355 (May) 1920.

15. Foster, Michael: A Text-Book of Physiology, ed. 3, New York, The Macmillan Company, 1880, p. 277.

Meltzer [16] and further supported by McMaster and Elman.[17] On the other hand, the experiments and observations of Winkelstein and Aschner,[18] Burget,[19] Chiray and Pavel,[20] Whitaker [21] and Berg [22] have led them to conclude that contrary innervation does not control the flow of bile into the duodenum, or at least it is not an important factor.

Nearly all observers agree that a constricting force is effective at times in closing the duodenal end of the common bile duct. Many believe this to be the action of an independent sphincter. Some observers [23] believe that the tonus of the duodenal musculature is an important, if not the most important, element of resistance. Numerous experiments have shown that the sphincter in animals possessing a gallbladder will withstand a pressure equal to that of a column of water from 100 to 625 mm. in height. Many factors influence the tonus of the sphincter. Removal of the gallbladder, feeding of the animal and the application of acids and certain drugs to the duodenum tend to reduce it, while fasting the animals and the application of alkalis to the duodenum tend to raise it.

Various methods have been used to study the sphincter action at the duodenal end of the choledochus and its relation to the flow of

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18. Winkelstein, A., and Aschner, P. W.: The Pressure Factors in the Biliary Duct System of the Dog, Am. J. M. Sc. **168**:812 (Dec.) 1924.

19. Burget, G. E.: The Regulation of the Flow of Bile, Am. J. Physiol. **74**: 583 (Nov.) 1925; The Regulation of the Flow of Bile: II. Effect of Eliminating the Sphincter of Oddi, ibid. **79**:130 (Dec.) 1926.

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21. Whitaker, L. R.: The Mechanism of the Gallbladder, Am. J. Physiol. **78**:411 (Oct.) 1926.

22. Berg, B. N.: Gall-Bladder Function After Division of Common Duct and Transplantation of the Proximal Segment, Surg., Gynec. & Obst. **46**:464 (April) 1928.

23. Burget (footnote 19). Carlson, A. J.: Physiology of the Liver; Present Status of Our Knowledge, J. A. M. A. **85**:1468 (Nov. 7) 1925. Copher, G. H., and Kodama, Schuichi: The Regulation of the Flow of Bile and Pancreatic Juice into the Duodenum, Arch. Int. Med. **38**:647 (Nov.) 1926. Graham, E. A.; Cole, W. H.; Copher, G. H., and Moore, Sherwood: Diseases of the Gallbladder and Bile Ducts, Philadelphia, Lea & Febiger, 1928, pp. 17, 34 and 59. Saunders, William: A Treatise on the Structure, Economy and Diseases of the Liver: Together with an Enquiry into the Properties and Component Parts of the Bile and Biliary Concretions, Boston, W. Pelham, 1797, 231 pp.

bile. The duodenum of anesthetized animals has been incised opposite the papilla so as to expose the papillary orifice, and various experiments have then been performed. Rost inserted a cannula into the duodenum of dogs and thus studied the flow of bile into it before and after cholecystectomy. The studies here presented substantiate many of his observations. A cannula has been inserted into the common bile duct toward the duodenum and the sphincteric action studied by the resistance offered; duodenal tubes have been inserted in order to detect the presence or absence of flow of bile; the sphincters have been abolished in some animals, and the reactions of such animals have been compared with those of animals with intact sphincters. McWhorter,[24] by cutting the distal mucosa, and Burget, by severing and transplanting the distal end of the duct, did not note any effect on resistance of the sphincter; however, this resistance had been lowered by laying the duodenal portion of the duct wide open.[25] Burget cocainized the orifice of the duct to eliminate any action of the sphincter that there might be, and noted the resistance then offered at the duodenal end of the duct and the effects of various drugs on it. He concluded that the function of the duodenal sphincter had been overemphasized, and that duodenal tonicity and peristalsis are significant in the regulation of the flow of bile.

The chief functions of the sphincteric action at the duodenal end of the choledochus are generally agreed to be: regulating the flow of bile into the duodenum, preventing back flow from the intestine into the duct and serving as a factor in the filling of the gallbladder.[26] Respiration, peristalsis and activity of the gallbladder have also been considered significant in the discharge of bile into the duodenum. Effects of various foods and drugs on the flow of bile have been studied extensively. Pavlov[27] noted that the administration of fat, meat extractives and gastric digestive products of white of egg was followed by a free flow of bile. Boyden[28] noted the emptying of the gallbladder

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26. Higgins, G. M., and Mann, F. C.: Observations on the Emptying of the Gallbladder, Am. J. Physiol. **78**:339 (Oct.) 1926.

27. Pavlov, I. P.: The Work of the Digestive Glands, ed. 2, Philadelphia, J. P. Lippincott Company, 1910, p. 149.

28. Boyden, E. A.: The Gall-Bladder in the Cat, Its Development, Its Functional Periodicity, and Its Anatomical Variation as Recorded in Twenty-Five Hundred Specimens, Anat. Rec. **24**:388 (Jan.) 1923; The Effect of Natural Foods on the Distention of the Gall-Bladder with a Note on the Change in Pattern of the Mucosa as it Passes from Distension to Collapse, ibid. **30**:333 (Aug.) 1925.

after a meal of fats and believed the regulatory action of the sphincter to be important. Many observers have noted that the passage of acid chyme into the duodenum or the application of dilute hydrochloric acid to the region of the papilla produces flow of bile into the duodenum. An extensive survey of the literature and some personal observations on the anatomy and physiology of the duodenal end of the choledochus were reported by Giordano and Mann.[29]

METHODS OF EXPERIMENTS

All operative procedures were carried out on dogs under ether anesthesia and with aseptic technic. The object of the surgical operations was to expose an isolated segment of duodenum containing the intramural portion and orifice of the

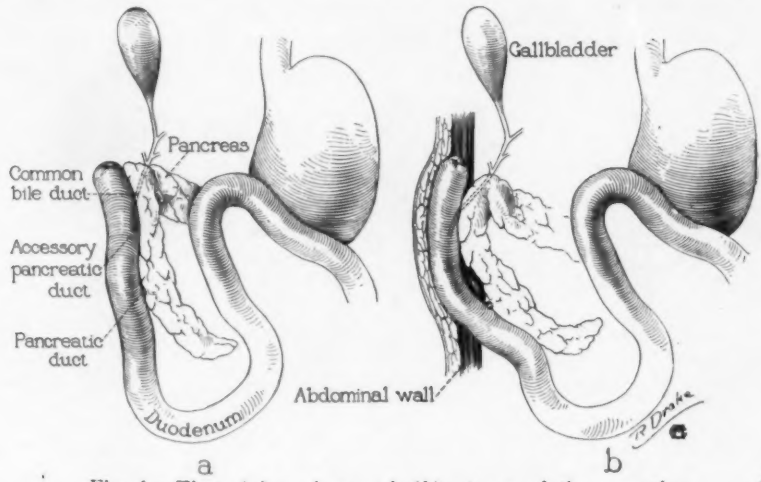

Fig. 1.—First (*a*) and second (*b*) stages of the operation.

choledochus in such a manner that the discharge of bile into the duodenum and the phenomena taking place at the orifice of the ampulla of Vater could be observed directly in intact animals. The intestinal tract was so rearranged that its content did not come in contact with the isolated segment of duodenum. The main pancreatic duct continued to empty into the intestine. Various procedures were employed to accomplish this, but it was found that the best results could be obtained by a three-stage operation, the technic of which is as follows:

First Stage (*Fig. 1, a*).—In this stage the pylorus is divided, the duodenal end is closed, and the upper part of the jejunum is united to the stomach. To accomplish this, either an anterior Polya operation may be employed, or after section of the pylorus and closure of both ends, gastrojejunostomy may be performed. Several weeks are allowed to elapse for the animal to recover fully.

Second Stage (*Fig. 1, b*).—The abdomen is again opened in the median line. The lesser pancreatic duct is isolated, cut close to the duodenum and evulsed. As

29. Giordano, A. S., and Mann, F. C.: The Sphincter of the Choledochus, Arch. Path. **4**:943 (Dec.) 1927.

this duct opens into the duodenum with or close to the orifice of the choledochus, it is destroyed to eliminate any complicating factors that pancreatic secretion might produce in later observations. The pancreas is separated from the duodenum for a slight distance proximal and distal to the entrance of the choledochus into the bowel, and the abdominal muscle and layers of fascia are closed through these openings under the duodenum. The skin is closed over the duodenal segment, and the animal is allowed to recover.

Third Stage (*Fig. 2*).—The skin is incised over the bulging duodenal segment and dissected from it. The duodenum is opened longitudinally opposite the orifice of the choledochus. The papilla of Vater and that of the main pancreatic duct are located, and the duodenum is divided midway between them. The distal end of the duodenum is closed, care being taken not to obstruct the main pancreatic duct. The edges of skin are trimmed away from the remaining duodenal segment.

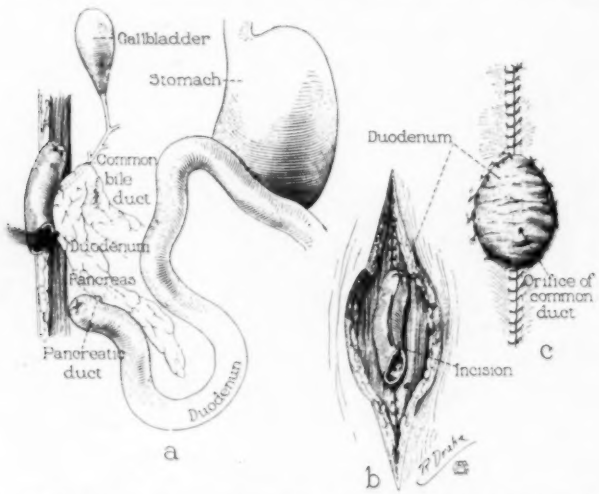

Fig. 2.—Third stage of operation: *a*, division of the duodenum between the papilla of Vater and the main pancreatic papilla; *b*, an isolated duodenal segment, showing the line of incision, and *c*, operation completed; the edges of the duodenal segment were sutured to the surrounding skin.

This segment, which contains the intramural portion and orifice of the choledochus, has already been opened. Its edges are sutured to the surrounding skin. If sufficient care is used in this stage of the operation, the peritoneal cavity need not be entered.

Observations were usually started several days after the completion of the operative procedures. The experiments were concerned only with direct observations of the exposed duodenal segment, the orifice of the choledochus and the flow of bile from it. Studies were made with the animals in fasting and in nonfasting states, and the effects of substances administered orally and subcutaneously and applied locally to the exposed duodenal segment were noted.

After the animals had thoroughly recovered from the third stage of the operation and had been observed for a length of time sufficient to obtain convincing data, the gallbladder was removed. This was done through a high left rectus

incision, the exposed portion of the duodenum and the choledochus being disturbed as little as possible. After recovery from this operation, similar studies were made to determine the effects of cholecystectomy.

RESULTS OF EXPERIMENTS

Observations on the series of animals that had a segment of duodenum containing the orifice of the choledochus exposed on the abdominal wall revealed certain constant physiologic phenomena. These will first be considered under various conditions in animals with the gallbladder intact.

After a fast of twelve hours or longer bile did not flow from the orifice of the choledochus during hours of observation. This was constant in all but two animals observed. Later exploration in one of these revealed a diseased gallbladder and a markedly dilated choledochus. In the other animal bile did not flow in the fasting state in early observations but later, particularly after catheterization of the choledochus, there was a moderate flow, at times, of yellow bile. One or two other animals occasionally expressed a drop of bile during violent muscular straining, but none was noted at any other time. The orifice of the choledochus was usually closed in the fasting state. However, this was not a constant observation. Frequently when the exposed duodenum contracted, the orifice dilated to varying degrees and gradually closed again. If the intestinal segment was very active, the ampulla would frequently remain open. On a few occasions visible dilatation occurred when intestinal activity was not observed.

The exposed segment of duodenum usually showed very little activity when the animal was deprived of food. At times mild contractions were visible; strong contractions seldom occurred. Often fairly long periods would elapse without visible activity. On a few occasions, when there was audible borborygmus, the exposed segment became more active. The mucosa was usually pallid or only slightly hyperemic. The amount of duodenal secretion was not great. By passing a catheter attached to a manometer through the orifice of the duct into the choledochus, the intraductal pressure was found to be from 140 to 170 mm. of bile.

Feeding produced marked and constant changes. There was almost invariably a flow of bile from the orifice of the choledochus. The bile was usually dark brown and viscid. Generally an initial flow occurred either at the sight and smell of food or during its ingestion. The bile oozed steadily and profusely for from one to three or four minutes and then the flow ceased partially or completely for from ten to twenty minutes. During that time, there was little duodenal activity.

A secondary profuse flow of dark brown, viscid bile began from ten to twenty minutes after feeding. It usually occurred as steady oozing which lasted from a few to fifteen minutes. The flow then occurred in brief oozes and spurts, gradually diminishing in amount and frequency after the first half to one hour and generally almost completely ceasing after from three to four hours. The bile gradually became lighter in color and less viscid. Occasionally the primary flow continued without interruption. On some occasions, the flow did not occur until from fifteen to thirty minutes after feeding, when it began and continued for several hours.

The relationship of other physiologic processes to flow of bile after feeding was studied. Immediately after operation and for the following week or ten days, spurts of bile were definitely related to respirations. Series of from two to twelve spurts would occur on successive respirations, with intervals of several minutes between such series. Deep inspirations were accompanied by large outpourings of bile. Gradually, as the duodenal segment recovered its tonus and activity, spurts of bile became less related to respiration and finally seemed to be scarcely influenced by it.

During the first week or ten days after operation, the exposed duodenal segment did not show visible activity. Gradually it regained its tonus and activity, and attained maximal recovery from two to three weeks after operation. After this time it was fairly consistent in its reactions. As has been noted, it showed little activity in the fasting state. Feeding sometimes produced an immediate increase of contractions for a few minutes, but generally it did not. During the first ten to twenty minutes after feeding, there was little visible change. During this time, bile usually oozed steadily; then the segment became more hyperemic and gradually increased in tonus and activity. Soon definite peristaltic waves could be seen. These contractions usually increased the quantity of bile into accompanying spurts. The amount of duodenal activity gradually increased and reached a maximum about half an hour after feeding. The flow of bile became more interrupted, occurring chiefly in spurts; these frequently were associated with contractions. However, all duodenal contractions were not accompanied by spurts of bile. Sometimes a discharge of bile would occur when there were no duodenal activity and no other visible stimulus. After a peristaltic contraction, the segment of bowel sometimes appeared to relax; the orifice dilated, and bile would pour out for several seconds.

Muscular straining sometimes produced small spurts of bile. Mild muscular movements usually had no effect. Active stretching of the animal or straining sometimes caused bile to be discharged, but only after feeding.

Psychic factors appeared to have some effect on the flow of the bile. In the fasting state excitement did not promote flow. The smell of food sometimes caused considerable outpouring of bile, and the primary discharge of bile with feeding must have been of psychic or reflex origin, as it began often before the meal had reached the stomach. Excitement sometimes delayed or inhibited the flow of bile. On one occasion, an animal that regularly expressed bile after feeding showed no flow of bile for an hour after the meal. During this time, several strangers were observing the animal and appeared to disturb him. Five minutes after the strangers departed, the animal became quiet and bile flowed profusely.

After a meal the orifice of the choledochus was usually patent. It would dilate with the spurting of bile and would remain open if the duodenum was active and spurts of bile were frequent. When the flow of bile and duodenal contractions diminished or became more interrupted, the orifice closed partially but not completely.

These responses to feeding were the usual observations following a meal of egg yolk and cream. Lean horse meat produced a rather similar response with some variations. Frequently the initial flow did not begin until from fifteen to thirty minutes after feeding. The bile often appeared lighter in color and less viscid than after a meal of fat. The flow of bile usually lasted longer after a meal of meat, and the quantity of hepatic bile was greater. Skimmed milk was followed by a flow of bile similar to that produced by lean meat. The effects of various types of foods on duodenal activity appeared to be the same. Water administered by mouth stimulated the exposed duodenum to increased activity, but did not produce a flow of bile. A saturated solution of magnesium sulphate administered by mouth was followed by violent contractions of the exposed duodenum and active purgation of the animal, but bile was not expressed. A meal of fat administered three hours later was followed by an immediate flow of brown, viscid bile.

After standardizing the responses of animals to various conditions and test substances, cholecystectomy was performed. Removal of the gallbladder was followed by definite changes in the flow of bile. In the fasting animal there was a constant flow. The bile was usually light in color and watery, but became somewhat darker, thicker and more scant as the fast was prolonged. It flowed in spurts and brief oozes associated with many factors. Respirations, especially if deep, often were associated with spurts of bile. Slight muscular effort produced similar results. Active stretching of the animal often was accompanied by considerable outpouring of bile. Duodenal contractions were also contributory causes of spurts of bile but were not significant

in the fasting state because the exposed segment showed little activity. The orifice of the choledochus was almost constantly patent. Feeding had the same effect on the exposed duodenum after cholecystectomy as with the gallbladder intact; that is, it produced a gradual increase of activity, secretion and hyperemia. It had very little effect on the flow of bile. There was no initial or subsequent outpouring of brown bile. For the first half hour the flow appeared similar to that before feeding, except that as the duodenal segment became more active spurts of bile became more related to this activity. However, there did not seem to be as close a relationship between peristalsis and spurts of bile after removal of the gallbladder as before it. The amount of bile gradually increased, and the color became somewhat lighter after a meal of lean meat. This was true to a much smaller degree after a meal of fat.

The intraductal pressure in the choledochus of the fasting animal after cholecystectomy was greatly reduced. Twenty-four hours after operation the pressure was found to be only from 20 to 30 mm. of bile. Subsequent readings showed a slight rise of pressure, but readings taken several months after cholecystectomy were never higher than 60 mm. of bile.

Various solutions were poured over the exposed segment of duodenum and the papilla of Vater in an effort to elicit any effects of local stimulation. The temperatures were varied, but this seemed to make little difference. Most solutions were used at body temperature. The following results were noted. Distilled water usually had no effect, though occasionally it stimulated duodenal contractions. Physiologic solution of sodium chloride acted similarly, but seemed to excite duodenal contractions more frequently. A solution of 25 per cent magnesium sulphate had an inconstant stimulating effect on the activity of the duodenal musculature but no evident independent action on the orifice of the choledochus. Usually bile did not flow after its use, but occasionally there were a few spurts of yellow bile. Dilute hydrochloric acid seemed to have a more constant stimulating effect on duodenal contractions, and its use was followed more frequently by small spurts of yellow bile. Alkalis in the form of dilute sodium hydroxide and sodium bicarbonate had no visible effect on the duodenum or orifice and did not promote flow of bile. Mechanical stimulation in the form of sponging was followed by contraction of the duodenal segment and orifice of the choledochus but never by the discharge of bile. The intravenous administration of bile salts was followed in half an hour by a profuse flow of light yellow, watery bile which lasted more than three hours (figs. 3 to 6).

COMMENT

It is difficult to determine what effect the anatomic sectioning and reconstruction, as performed in these experiments, had on the innervation and function of the extrahepatic biliary tract and the isolated

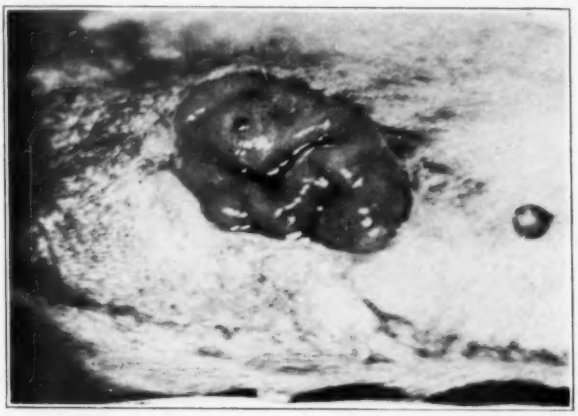

Fig. 3.—Animal in fasting state. The orifice of the choledochus is patent, but there is no flow of bile.

Fig. 4.—Same animal as in figure 3, fifteen minutes after the meal of fat. Dark brown bile is flowing profusely from the orifice of the choledochus.

segment of duodenum. Most of the vagal branches of this region were divided, but the sympathetic nerves that follow the hepatic artery were left intact. However, as apparently normal activity returned to the exposed segment of bowel and as the flow of bile responded to stimuli in what is thought to be a normal manner, it seems justifiable

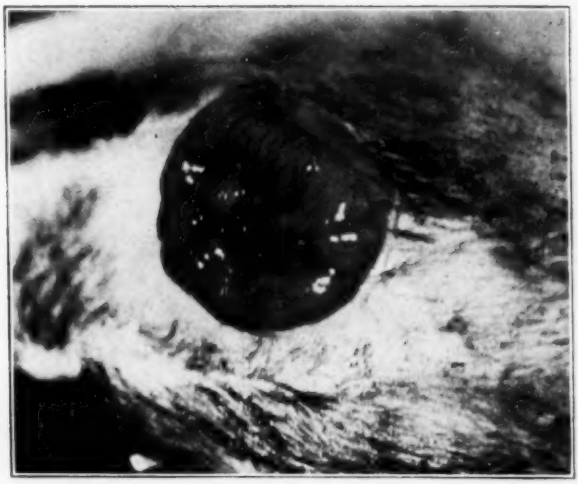

Fig 5.—Exposed segment of duodenum. Animal in fasting state. The segment is relaxed, and there is no flow of bile.

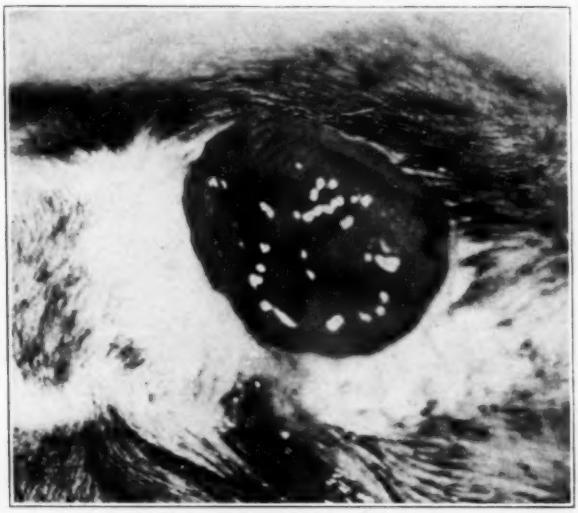

Fig. 6.—Same animal as in figure 5, after a meal of fat. The duodenal segment shows an increased tonus, and bile is flowing from the orifice.

to assume that normal physiologic processes were not greatly disturbed. By this method of study the effects of anesthesia and the immediate effects of operative trauma could be avoided. Subsequent observations showed the significance of this, as responses soon after operation were different from those obtained when the animal had completely recovered from the operative procedures. The animals were trained to lie quietly on the table for hours at a time, and their normal responses were well established before each test substance was given or observation procedure carried out. The observations on the various animals in this series agreed with and confirmed those made on the other members of the series.

It was found that bile did not flow from the orifice of the choledochus in the fasting animal with an intact normal gallbladder. An animal in which bile flowed in the fasting state was found to have a diseased gallbladder and a markedly dilated choledochus. Another animal responded normally at first, but later, after the orifice of the duct had been traumatized, some bile flowed when the animal was fasting. Later, however, bile again ceased to flow in the fasting state, suggesting that the regulatory mechanism was temporarily disturbed. The absence of the discharge of bile in the fasting state must be due to one of two factors: Either there are insufficient bile and bile pressure in the choledochus to cause a flow of bile from the orifice, or there is a sphincter mechanism at the duodenal end of the choledochus preventing the discharge of bile. Various observers have shown that the first of these could not be the cause. With a T-tube in the common bile duct, Potter and Mann [30] found an average intraductal pressure of 95 mm. of bile. McMaster and Elman sectioned the choledochus in animals that had been deprived of food and found that the pressure at the proximal end rose to from 100 to 150 mm. of bile. Nuboer [31] determined that the pressure in the choledochus in fasting dogs was from 90 to 100 mm. of water. In the series here presented, animals in a fasting state were found to have an intraductal pressure in the choledochus of from 140 to 170 mm. of bile. When the manometer was turned down and the bile was allowed to flow out, a considerable quantity was obtained. These experiments suggest that there is sufficient pressure in the choledochus in fasting animals to induce flow of bile from the orifice if the flow is not prevented by a sphincter mechanism. Is this sphincter action produced by duodenal tonus and

30. Potter, J. C., and Mann, F. C.: Pressure Changes in the Biliary Tract, Am. J. M. Sc. **171**:202 (Feb.) 1926.

31. Nuboer, J. F.: Die Funktion des Oddischen Muskels, abstr. Ber. ü. d. ges. Physiol. **51**:81, 1929.

activity alone or does some other sphincter mechanism play a part? There are several factors that argue against the former contention. The flow of bile apparently is not dependent on duodenal activity alone because the smell of food may cause a flow of bile when visible change cannot be seen in the exposed segment. After the animal has been fed, the discharge of bile often occurs when the segment is quiet. Also in the fasting state the exposed segment may become very active without discharge of bile. This was noted especially after the oral administration of water and of magnesium sulphate solution. These observations suggest a special sphincter mechanism. Many anatomic studies have been made of the duodenal portion of the choledochus, and arrangements of muscles that could act as a sphincter have been described as being around the orifice of the duct and around the portion of the duct that traverses the duodenal musculature. Hendrickson described a complete muscle ring around the end of the duct and just under the mucosa, which he believed constituted the sphincter of the common bile duct. It does not seem likely that this alone constitutes the sphincter, because frequently in the fasting animal the orifice of the duct was widely dilated and the lumen of the duct was visibly open for several millimeters but bile did not flow. There is apparently a sphincter mechanism in the intramural portion of the choledochus which is not entirely dependent on duodenal tonus and activity.

In these experiments it was found that feeding was followed by a flow of bile. There was usually a primary flow of brief duration. This was not a result of stimulation due to absorption of food because the flow often began when the animal sighted and smelled the food, but before it had ingested any of it. At other times the flow began with the beginning of ingestion of food, before the substance had had time to reach the stomach. The primary flow was evidently a reflex response to psychic stimulation. The initial flow usually lasted only from one to three minutes and occurred as a profuse steady ooze. The flow usually diminished or ceased during the next ten to thirty minutes. The secondary flow then began and continued for several hours. It began after some of the food had had time to be absorbed. Bile flowed first in prolonged oozes which gradually became of shorter duration and were largely replaced by spurts. Several factors were associated with the spurting of bile. The most significant of these appeared to be duodenal activity. As the duodenum gradually became more active after feeding, spurts of bile frequently accompanied its contractions. Sometimes after a contraction the exposed segment of duodenum relaxed and bile flowed for a few seconds. However, all spurts of bile were not associated with visible duodenal activity. Respi-

ration was definitely related to spurts of bile soon after operation, before the exposed duodenum had recovered its tonus and activity. After the effects of operative trauma had disappeared and the exposed bowel was healed and active, respiration had little effect on the discharge of bile. Contractions of the abdominal musculature were occasionally accompanied by spurts of bile, but this accounted for only a small percentage of the bile discharged. Excitement often seemed to have an inhibitory influence on the discharge of bile. Spurts of bile were occasionally observed independent of any visible factors, and suggested the possibility of contraction of the gallbladder as a cause. This was not proved.

The type of food administered had some effect on the responding flow of bile. Both fats and lean meat produced a flow, but the former often called forth a prompter flow, and the bile was frequently darker and more viscid. However, the flow after fats did not last as long as after lean meat. The latter did not produce so profuse an immediate flow, but the total quantity was larger, the flow lasted longer, and the bile was of a more hepatic type, especially after the first half hour.

Cholecystectomy had a definite and constant effect on the flow of bile from the duodenal end of the choledochus. There was always a flow in the fasting state. This occurred chiefly in spurts accompanying slight activities, such as respiration, duodenal contractions or movements of the animal. Frequently spurts occurred independent of any visible stimulus. They were not forceful, and the bile did not seem to be under tension. The orifice of the choledochus was almost always open. The intraductal pressure in the choledochus was very low, from 10 to 20 mm. of bile, soon after operation. This was found to be the case within twenty-four hours of operation. It has been supposed that the loss of sphincter action following cholecystectomy was due to an overpowering and paralyzing action of the secretory pressure of the liver on the muscle after the concentrating activity of the gallbladder had been removed. It hardly seems likely that the sphincter could be paralyzed as soon after cholecystectomy as occurred in these experiments, and a possible reflex loss of tonus is suggested.

Foods did not alter the flow of bile immediately after cholecystectomy. The quantity of bile slowly increased after feeding, suggesting stimulation of hepatic secretion. The bile became less viscid and lighter yellow. As the duodenum responded to food and became more active it influenced the discharge of bile to a greater extent than before feeding, but less than it did before cholecystectomy.

Various solutions applied to the exposed segment had little effect. They sometimes caused a slight increase of duodenal activity and occasionally a spurt of bile. The responses did not vary sufficiently

with different test substances to permit any definite deductions. As only a small portion of duodenum was exposed in these animals, it would not be fair to draw conclusions regarding the effects of these substances on the entire duodenum. However, it seemed evident that they had little direct effect on the orifice of the choledochus.

An interesting observation was made on the effect of fasting and feeding on duodenal activity. The isolated segment of bowel was relatively inactive in the fasting state and became definitely more active after feeding. There was also an increase of hyperemia and an apparent increase of duodenal secretion. As food did not come in direct contact with the isolated bowel these responses could not have resulted from actual contact with food or distention of the segment and must have resulted from stimulation transmitted by either nervous or vascular routes.

SUMMARY

The object of this experimental investigation was to study some of the factors concerned in the physiology of flow of bile into the duodenum. Operative procedures were devised that provided animal subjects with an isolated segment of duodenum exposed on the abdominal wall. This segment of bowel was opened longitudinally and sutured to the surrounding skin. It contained the orifice and the intramural portion of the choledochus. The accessory pancreatic duct was evulsed to avoid any complicating factors that it might produce. As the exposed duodenum was isolated from the remainder of the bowel, the intestinal contents did not come in contact with it. These animals lived for months in an apparently normal condition and permitted observations uncomplicated by the effects of anesthesia and the immediate effects of operative trauma. Studies were made with the animals in fasting and in nonfasting states. The effects of various test substances administered orally, intravenously and locally to the exposed segment of duodenum were determined. After completing these observations, the gallbladder was removed and similar studies were repeated to determine the influence of cholecystectomy.

The following observations and deductions were made: In the fasting animal with an intact normal gallbladder, the orifice of the choledochus was usually closed, the exposed duodenal segment was relatively inactive, and there was almost never flow of bile. The intraductal pressure in the choledochus was found to be from 140 to 170 mm. of bile. The absence of flow of bile was evidently due to a sphincter mechanism at the duodenal end of the choledochus. The tonus of the duodenal musculature apparently was not the sole cause of the sphincter action, and a special sphincter mechanism was suggested.

Food stimulated flow of brown viscid bile. There was usually an initial ooze beginning with the ingestion of food and lasting for from one to three minutes. This was apparently due to psychic or reflex stimulation. A secondary flow began from ten to thirty minutes later and lasted several hours. The bile flowed in brief oozes and spurts, which were frequently related to activity of the exposed duodenum but often occurred independently. Respiration was not a significant factor in the discharge of bile. The exposed segment of bowel became more active and more hyperemic after feeding and reached a maximal degree of peristalsis about half an hour after the ingestion of food.

After cholecystectomy, bile continued to flow in the fasting as well as in the nonfasting state. It was lighter in color and less viscid than the bile that flowed after an animal with an intact normal gallbladder had been fed. Feeding had little effect on the discharge of bile other than to increase the quantity slightly. The orifice of the choledochus was constantly patent. Duodenal activity and its response to feeding were not influenced by cholecystectomy. After removal of the gallbladder, the intraductal pressure in the choledochus of the fasting animal was reduced to from 10 to 20 mm. of bile.

Bile salts administered intravenously produced a profuse flow of thin yellow bile. Solutions applied locally to the exposed segment of duodenum occasionally stimulated a slight degree of duodenal activity and rarely were followed by the expulsion of a drop of bile, but generally they did not produce a definite response.

SPONTANEOUS PEPTIC ULCERS OF DUODENUM AFTER CONTINUED LOSS OF TOTAL PANCREATIC JUICE *

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In a previous paper [1] from this laboratory mention was made of the finding of peptic ulcerations of the duodenum just distal to the pylorus in a dog that lost the entire external secretion of the pancreas and was kept alive and in good condition for two weeks with daily intraperitoneal injections of Ringer's solution. This observation was so striking and so unexpected that a number of other dogs were subjected to the same experimental procedure. Duodenal ulcers were found in every case. This finding, as will be pointed out, is not surprising after all and seems to fit in with a number of related observations by others.

PREVIOUS WORK

Most of the tremendous amount of work that has been done on experimental peptic ulcers has dealt with those on the gastric side of the pylorus. These observations have been successively reviewed by many authors. MacCallum,[2] in 1904, reviewed most of the earlier experiments that were largely concerned with the production of mucosal defects in a variety of ways. In a book by Rost [3] most of the literature up to 1921 has been analyzed. More important, however, than the actual production of a lesion is the study of the factors that keep it from healing, and hence, lead to chronicity. Thus, it has been repeatedly shown that the mucous membrane of the stomach has a remarkable regenerative power so that the removal of large areas of mucosa is rapidly followed, usually within two weeks, by complete healing. There is also abundant clinical evidence to show that duodenal ulcers are also prone to heal spontaneously only to recur and heal again under a variety

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1. Elman, R., and Hartmann, A. F.: Cause of Death Following Rapidly Total Loss of Pancreatic Juice, Arch. Surg. **20**:333 (Feb.) 1930.

2. MacCallum, W. G.: Am. Med. **8**:452, 1904.

3. Rost, F.: Pathologische Physiologie des Chirurgen, ed. 2, Leipzig, F. C. W. Vogel, 1921, p. 102.

of circumstances. Many such cases have been followed by fluoroscopic and by roentgenologic examinations. It is probable, indeed, that much of the dispute and disagreement as to the results following various modes of treatment is explainable on this basis. Whatever the primary cause of peptic ulceration, whether it is vascular, neurogenic, bacterial or traumatic, the factors promoting its chronicity would seem to be of most practical and theoretical importance. Prominent among these factors are high acidity and roughness of the gastric contents. Rost [3] as well as McCann [4] summarized most of this work in some detail. High acidity will be discussed later. It should be emphasized here that experimental work done with dogs is probably of greater significance than that performed on other animals. Dogs are particularly suited for the study of duodenal ulcers since this lesion practically never occurs normally, as shown by a study of 1,000 routine autopsies on dogs reported by Ivy.[5]

In this paper we are concerned specifically with the observations of spontaneous duodenal ulcerations noted during the course of experiments in which the total pancreatic juice was drained to the outside. A number of observations by other workers fit in with the present experiments. Most important, perhaps, are ulcers noted by Mann and Williamson [6] which also occurred just distal to the pylorus in dogs and which developed following diversion of the entire duodenal contents. This was achieved by an operation they termed "surgical drainage of the duodenum." By this procedure the entire contents of the duodenum were made to empty low down by resecting it, closing one end and suturing the other end into the terminal ileum. The pylorus and the jejunum were then anastomosed end-to-end. Peptic ulcers, some perforating, were noted just distal to this line of suture in fourteen of sixteen dogs. They were explained by the assumption that diversion of the alkaline duodenal contents permitted the acid gastric juice to attack and ulcerate the jejunal mucosa. These observations have been abundantly confirmed first by Morton [7] in all of eighteen dogs and recently by Weiss [8] and also by Dragstedt.[9] It is of special interest that Morton noted that "duodenal drainage" prevented healing and resulted in chronicity of experimental mucosal defects in the stomach in 50 per cent of his animals.

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4. McCann, J. C.: Experimental Peptic Ulcer, Arch. Surg. **19**:600 (Oct.) 1929.

5. Ivy, A. C.: Physiology of the Stomach: Studies on Gastric Ulcer, Arch. Int. Med. **25**:6 (Jan.) 1920.

6. Mann, F. C., and Williamson, C. S.: Ann. Surg. **77**:409, 1923.

7. Morton, C. B.: Ann. Surg. **85**:207, 1927.

8. Weiss, A. A., and Gurriaran, G.: Bull. et mém. Soc. nat. de chir. **56**:8, 1930.

9. Dragstedt, L. R.: Personal communication.

In many other analogous experiments peptic ulcers at the exit of the stomach have been described which also have an important bearing on the present findings since they concern drainage of alkaline duodenal contents or interference with their normal behavior. Thus Grey [10] noted during the course of transplantation experiments in two dogs that peptic ulcerations of the duodenum occurred after pancreatic and bile ducts were made to empty in the terminal ileum. Mann and Williamson [6] also performed this experiment on a large number of dogs, thirty of which survived eight days or longer; duodenal ulcers were found in ten. Bickel,[11] in 1909, extirpated the duodenum in a dog, transplanted the bile and pancreatic ducts into the abdominal wall and reestablished intestinal continuity by a gastro-enterostomy. After four and one-half weeks, the animal died. Peritonitis from a perforating ulcer of the jejunum at the stoma was found at autopsy.

Similar experiments were reported by Exalto [12] in 1911. He noted that jejunal ulcerations were always present at the stoma of an experimental gastro-jejunostomy provided the duodenum was transplanted so as to empty its contents low in the gastro-intestinal tract. Baggio,[13] an Italian surgeon, has recently found similar ulcerations just distal to the emptying point of the stomach in four of six dogs subjected to a gastric resection by a "Y-anastomosis of Roux," an operation in which the gastric juice pours directly over the unprotected jejunal mucosa, the duodenal contents draining a little lower down. Dott and Lim [14] reported that marginal ulcers were nearly always formed after an experimental gastro-enterostomy whenever the pylorus was occluded. This agrees with the clinical experience of von Haberer [15] who found that jejunal ulcers developed in 12 of 71 cases with pyloric occlusion in which he performed a gastro-enterostomy, whereas they developed in only 3 of 275 cases without occlusion. The latter findings were assumed to be due to the fact that closing of the pylorus precluded duodenal reflux and hence the unneutralized gastric contents poured directly on the jejunal mucosa. Ordinarily this does not occur, since it is well known that whatever the modus operandi of a gastro-enterostomy in the absence of organic pyloric stenosis most of the gastric contents leave the stomach via the pylorus and not the stoma.[3]

10. Grey, E. G.: Surg., Gynec. & Obst. **28**:36, 1919.

11. Bickel, A.: Berl. klin. Wchnschr. **46**:1201, 1909.

12. Exalto, J.: Mitt. a. d. Grenzgeb. d. Med. u. Chir. **23**:13, 1911.

13. Baggio, G.: Ann. ital. di chir. **3**:583, 1924; abstr., Surg., Gynec. & Obst. **40**:26, 1925.

14. Dott, N. M., and Lim, R. K. S.: Quart. J. Exper. Physiol., supp., 1923, p. 109.

15. von Haberer, H.: Deutsche Ztschr. f. Chir. **172**:1, 1922.

All of the experimenters thus far have explained these ulcers mainly on a chemical basis as due to the removal of or interference with the normal neutralizing effect of the alkaline duodenal secretions on gastric acidity. A dissenting opinion was recently voiced by McCann [4] on the basis of his own experiments. He diverted the duodenal contents by the method of Mann and Williamson,[6] but sutured the duodenum into the fundus of the stomach rather than into the terminal ileum. He studied the gastric acidity before and after the operation and found it unchanged. Ulcerations distal to the pylorus in his experiments, moreover, were just as frequent as when the duodenum was sutured into the terminal ileum. He inferred, therefore, that the neutralizing effect of the alkaline duodenal contents on gastric acidity had nothing to do with the formation of the ulcers and that mechanical rather than chemical factors were largely responsible for them. While the observations are clearcut and definite, the studies of gastric acidity, unfortunately, were made with a test meal of ground meat which, as is well known, combines so readily with hydrochloric acid as to mask to a considerable extent the actual acidity developed. Diametrically opposed findings, moreover, have been reported by Steinberg, Brougher and Vidgoff,[16] who used a test meal of 300 cc. of water containing Liebig's extract of beef. These workers found a much higher acidity following "duodenal drainage" into the terminal ileum. That the high acidity was due to faulty neutralization was shown by their use of an "acid test meal" which was much more slowly and incompletely neutralized than normal. These workers also proved that the difference in acidity was not due to alterations in the secretory activity of the stomach, for the juice from a Pavlov pouch showed no alteration in its acid content. The finding of ulcers in the experiments of McCann, finally, may not be in disagreement with those already mentioned. Anastomosis of the resected duodenum to the stomach does not necessarily mean free and continuous drainage, for it seems not improbable that the depth and strength of gastric peristalsis would tend rather to drive gastric contents into the loop or at least seriously interfere with an effective flow of the duodenal contents into the stomach. Neutralization of gastric acidity by the alkaline pancreatic juice might thus be seriously interfered with and the experiment, indeed, be one analogous to those in which the duodenum is sutured into the terminal ileum.

Spontaneous duodenal ulcers of a similar nature and at the same site, i. e., just distal to the pylorus, were noted by Kapsinow [17] in

16. Steinberg, M. E.; Brougher, J. C., and Vidgoff, I. J.: Changes in Chemistry of the Contents of Stomach Following Gastric Operations, Arch. Surg. **15**:749 (Nov.) 1927.

17. Kapsinow, R.: Ann. Surg. **83**:614, 1926.

seventeen of forty-three dogs in which the total bile was diverted to the outside for two weeks or longer. Bile drainage was effected by anastomosis of the gallbladder to the right renal pelvis, followed by ligature of the common duct, so that the entire bile flowed into and was excreted from the urinary bladder on micturition. The dogs were in poor condition at autopsy, however, and it seems difficult to know just what part inanition played in the formation of the lesion. Similar ulcerations were described recently by Berg and Jobling [18] in thirteen of twenty-three dogs in which the total bile was excluded from the duodenum by drainage to the outside, by total biliary obstruction or by drainage followed by obstruction. Some of their dogs showing ulcers at autopsy also had pneumonia. Their drainage experiments were performed by the closed collecting system first described by Rous and McMaster.[19] In contrast to these findings are the original observations of the latter workers, who make no note as to the presence of duodenal ulcers. One of us (Dr. Elman) has observed a great many such dogs with bile fistulas, all kept in excellent physical condition, some for as long as four months, without noting such a lesion.

METHODS

The intubation of the main pancreatic duct in dogs so as to obtain the total external pancreatic secretion has been described in detail elsewhere.[20] By this technic the secretion was obtained under sterile conditions from the entire pancreas and for the entire twenty-four hours, as described in a previous paper. Such a loss of pancreatic juice soon leads to a fatal outcome.[20] In the present experiments life was maintained in spite of continued drainage by the daily administration of 500 cc. of "combined solution" [21] in 5 per cent dextrose, intraperitoneally. Pancreatic juice was collected daily with aseptic precautions, and by culture or the examination of the sediment from a centrifugated specimen, the presence or absence of infection was ascertained. Whenever infection occurred, the animal was chloroformed and autopsy performed. Drainage was maintained for at least thirteen days in the present experiments. The animals were fed carefully, the average daily diet consisting of 500 cc. of milk, 200 Gm. of chopped lean meat, either cooked or raw, and several dog biscuits. The operations were all carried out under complete morphine-ether anesthesia. At the termination of the experiment the animals were killed with chloroform, and autopsy performed immediately. Frequent analyses of the main chemical constituents of the blood were made.

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18. Berg, B. N., and Jobling, J. W.: Bilary and Hepatic Factors in Peptic Ulcers, Arch. Surg. **20**:997 (June) 1930.

19. Rous, P., and McMaster, P. D.: J. Exper. Med. **37**:11, 1923.

20. Elman, R., and McCaughan, J. M.: J. Exper. Med. **45**:561, 1927.

21. Hartmann, A. F., and Elman, R.: J. Exper. Med. **50**:387, 1929.

RESULTS

One large ulcer was found just distal to the pylorus on the posterior or superior aspect of the duodenum in each of the six dogs studied. In some dogs one or two smaller ulcers were noted a few millimeters distally. The ulcers were generally round or oval, but in dog 235 (fig. 1) the edges were irregularly oval and in dog 12 (fig. 2) the ulcer was

Fig. 1 (dog 235).—From a photograph of two ulcers just distal to the pylorus (*P*).

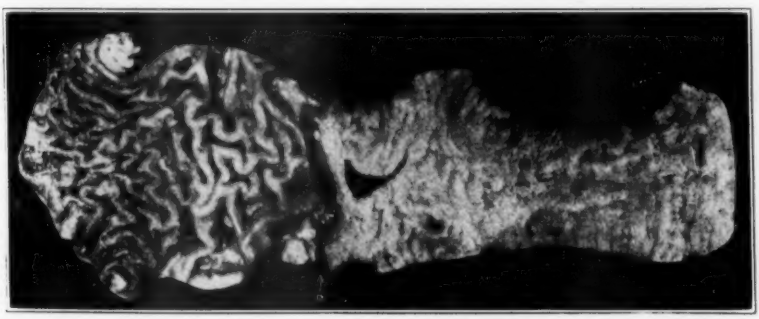

Fig. 2 (dog 12).—From a photograph of a single ulcer just distal to the pylorus (*P*).

semilunar. In several, blood clots were present over the lesion, but they could readily be removed. Bleeding was not infrequent, since streaks of blood were usually found in the jejunal contents at autopsy and often in the stools during life. Except possibly in dog 235 (fig. 3), no tendency to perforation was noted, which is not surprising in view of the relatively short duration of the experiments. On the other hand, no evidence of healing was seen. The microscopic study of the lesion

also did not show any sign of regeneration, the base extending down to the muscularis, which was edematous and frequently not even covered with granulation tissue. Figures 3, 4 and 5 were made from microscopic sections from three of these dogs. The table shows the amount of secretion collected and the duration of the experiments in each case. The stomach showed no abnormalities, nor were any other lesions found elsewhere. The peritoneum in each case was glistening, the operative wounds had healed and no evidence of infection in the pancreas or collecting system made out.

Fig. 3 (dog 235).—Sketch from a cross-section of a large ulcer, showing beginning penetration at one point (*P*).

Fig. 4 (dog 12).—Sketch from a cross-section of a large ulcer showing absence of granulation and healing.

Fig. 5 (dog 23).—Sketch from a cross-section of a large ulcer. High magnification of this and other ulcers show signs of inflammatory reaction at the base.

It should be emphasized that the general condition of these dogs was good. They were killed in each case only because of accidental infection of the pancreatic juice, because the flow suddenly stopped, owing to a kink or other obstruction to the collecting system, or because it was deemed that sufficient time had elapsed to demonstrate the lesion. There was, it is true, definite and once marked loss of weight, but the dogs were lively, active, alert and ate fairly well despite certain evidences of gastric irritability already reported in previous papers.[22] The food was

22. Elman and Hartmann (footnote 1). Elman and McCaughan (footnote 20).

taken, in general, more slowly than normally, and water and milk were lapped only at infrequent intervals and in small amounts. Dry dog biscuit was most relished, although meat was also eaten, some preferring it raw and others cooked. Vomiting sometimes occurred spontaneously. It was particularly apt to develop if milk or water was taken rapidly. If 300 cc. of milk was given by gavage, it would invariably be thrown up soon afterward. The chemical study of the blood showed little or no deviation from normal.

Though no special control animals were observed, it may be noted that in a great many previous experiments in which the pancreatic duct had been intubated for periods of one week or less, duodenal ulcers were never observed. Intraperitoneal solutions have also been injected into a great many dogs for a variety of reasons and ulcers never occurred in them.

Summary for Dogs with Duodenal Ulcer Draining the Total Pancreatic Juice

Dog	Weight, Kg.	Sex	Days of Drainage	Average Output of Pancreatic Juice per 24 Hours, Cc.	Comment
11	10	F	14	364	Eats only cooked meat and biscuits
235	13	M	15	345	Eats raw meat and biscuits; vomited once
125	8	M	13	302	Drinks milk well but slowly
12	9	M	18	394	Eats biscuit well; vomited several times
23	15	F	13	431	Eats meat and biscuits; vomited twice
27	7	F	15	315	Eats well but very slowly

COMMENT

Although the number of experiments performed are few, the constancy of the finding indicates that we are dealing with a definite mechanism capable of producing peptic ulcers of the duodenum. The assumption seems justified that the presence of pancreatic juice in some way protects the duodenum, since its mere diversion to the outside and in the absence of any other demonstrable changes brings about spontaneous peptic ulcers. The present experiments suggest, moreover, that the ulcers produced by experimental "duodenal drainage" and by other similar devices as reported by the many observers previously noted are undoubtedly due, not to the diversion of bile or duodenal secretions or to mechanical factors, but to the absence of pancreatic juice alone. Certainly the location of the lesion at the exit of the stomach and its appearance are similar in all cases, and in the present experiments all other factors have been excluded. Thus the entire gastro-intestinal and biliary tracts were left intact, only the pancreatic ducts being tied and intubated. That the present experiments probably have a greater bearing on the occurrence of this lesion in man is suggested, too, from the fact that

unlike some of the experiments referred to, the lesions develop in duodenal and not jejunal mucosa and in the presence of a normal pylorus and intestinal continuity.

The possibility that bile may also play a part in protecting the duodenum from ulceration is indicated by the experiments already mentioned. It is significant, however, that they were found in a relatively small proportion of the experiments performed and in some were complicated by inanition and other diseases. Bile, moreover, is not an alkaline secretion, as is frequently assumed, but normally is actually acid in reaction.[23] It could not play any part, therefore, in the neutralization of gastric acidity, except possibly by mere dilution. In any case, the rôle of bile must be a minor one as compared with that of pancreatic juice in the development of the duodenal ulcers under discussion.

How may we explain the protective action of the pancreatic juice in these experiments? The assumption may be and has been made that acid gastric contents injure the duodenal mucosa because it is not neutralized by the alkaline pancreatic juice. Extensive study of test meals and fractional analyses of gastric contents has led to the general belief, however, that neutralization of gastric acidity occurs on the proximal rather than the distal side of the pylorus. Recent observations, moreover, have tended to show that this neutralization occurs largely by reflux of pancreatic juice into the stomach. The evidence in support of this theory has been discussed in detail in previous papers from this laboratory.[24] The recent observations of Dragstedt and Ellis [25] lend further support to this theory. They found that gastric juice collected from the whole isolated stomach always contained a high level (0.4-0.5 per cent) of hydrochloric acid, thus showing the absence of any intrinsic neutralizing mechanism in the stomach itself as claimed by McClean [26] and others. Obviously, if this is true, the rôle of the pyloric muscle in controlling reflux is an important one, as will be referred to again.

The defect causing ulceration, according to this theory, lies in the inadequate preparation of gastric contents for reception by the duodenum, more specifically, in its inadequate acid neutralization. This conception is in accord with many of the experiments already referred to. Thus, it shows how the duodenal diversion experiments prevent adequate neutralization of gastric acidity, which remains high, as was directly

23. Drury, D. R.; McMaster, P. D., and Rous, P.: J. Exper. Med. **39**:403, 1924.

24. Elman, R.: Probable Influence of Pancreatic Juice in Regulation of Gastric Acidity, Arch. Surg. **16**:1256 (June) 1928; Surg., Gynec. & Obst. **49**:34, 1929. Olch, I. Y.: Duodenal Regurgitation as Factor in Neutralization of Gastric Acidity, Arch. Surg. **16**:125 (Jan.) 1928.

25. Dragstedt, L. R., and Ellis, J. C.: Am. J. Physiol. **93**:407, 1930.

26. McClean, H., and Griffiths, W. J.: J. Physiol. **66**:356, 1928.

demonstrated by Steinberg and his co-workers.[16] It explains the frequency of jejunal ulcers at a gastro-enterostomy stoma where the pylorus has been occluded or where the duodenal contents have been diverted, since in this way duodenal regurgitation is prevented. The infrequency of marginal ulcers following gastro-enterostomy in cases in which there is actual pyloric stenosis does not necessarily disqualify this explanation, for in these cases the prolonged gastric dilatation and stagnation has already rendered the stomach incapable of developing a normal acidity to begin with.

Further evidence that fits in with this theory is the experimental production of high gastric acidity and ulcers by partial pyloric occlusion. Thus, Friedman and Hamburger [27] were able to show an increase in gastric acidity after narrowing of the pylorus by the application of a circular silk suture, an experiment that we performed in this laboratory with similar results. They also showed that following the procedure, experimental defects of the gastric mucosa failed to heal and frequently developed into peptic ulcers. In two dogs, moreover, spontaneous duodenal ulcers were found, one of which had perforated. Bolton [28] showed, too, that healing of experimental ulcers was greatly prolonged if a rubber band were placed around the pylorus so as to constrict it. Similar delay has been reported by Ivy.[5] Hughson,[29] in a converse experiment, showed an acceleration in the healing of ulcers if the pylorus were "splinted" so it could not contract. Elman and Rowlette [30] finally were able to demonstrate a lowering of gastric acidity as shown by a more rapid neutralization of an acid test meal following successful division of the pyloric muscle.

These observations all tend to explain the correlation between duodenal ulcerations, high gastric acidity and hyperactivity of the pylorus which has long been noted clinically. The development of a high gastric acidity in clinical instances of duodenal ulcerations is explained by the diminished reflux of pancreatic juice due to increased pyloric tone. A number of proved cases of duodenal ulcerations were studied in this clinic and marked diminution of acid neutralization in the stomach noted in all.[31] Pylorospasm from whatever cause by diminishing duodenal reflux promotes a high gastric acidity which may be the only necessary factor needed to prevent traumatic,

27. Friedman, J. C., and Hamburger, W. W.: Experimental Chronic Gastric Ulcer, J. A. M. A. **63**:380 (Aug. 1) 1914.

28. Bolton, C.: Proc. Roy. Soc., London s.B., **82**:233, 1909-1910.

29. Hughson, W.: Relation of Pylorus to Duration of Experimental Gastric Ulcer, Arch. Surg. **15**:66 (July) 1927.

30. Elman, R., and Rowlette, A. P.: The Rôle of the Pyloric Sphincter in the Behavior of Gastric Acidity, Arch. Surg. **22**:426 (March) 1931.

31. Elman (footnote 24, second reference).

mechanical or other erosions from healing and, indeed, from developing into a peptic ulcer. On the other hand, a pyloric ulcer causes spasm which in turn promotes hyperacidity leading to a vicious circle and progression of the lesion. Pylorospasm itself is known to develop reflexly from other lesions in the abdomen thus explaining the not infrequent association of duodenal ulcerations, appendicitis and cholecystitis. That pylorospasm may occur on a neurogenic basis was promulgated years ago by Eppinger and Hess [32] on the basis of their concept of vagotonia. Certainly much clinical study has shown that symptoms of pylorospasm and duodenal ulcerations may develop from or be aggravated by psychic factors presumably mediated through the vagus nerve.

The importance of the pylorus in the treatment for duodenal ulcerations thus lies, in part at least, in its effect on the control of gastric acidity. Various operations have been designed, in fact, aiming, by removal of part of the muscle, to prevent pylorospasm. In a number of cases of pylorospasm without ulcer, Finney and Friedenwald [33] performed a pyloroplasty and achieved clinical cures. Recently Morton [34] and Archer [35] called attention to cases of hypertrophy of the pylorus in adults on whom the Rammstedt operation was done with complete cures. Further study may show that this simple procedure may be all that is necessary for the relief of early pylorospasm with or without ulcer.

SUMMARY

Spontaneous peptic ulcers were observed in six dogs that lost the total pancreatic juice for thirteen or more days and were kept alive and in good condition by careful feeding and the daily intraperitoneal administration of 500 cc. of Ringer's solution. These observations together with those of others point to the importance of the pancreatic juice in protecting the duodenal mucosa, most likely through its control of gastric acidity by reflux into the stomach. The clinical application of these findings to high gastric acidity, pylorospasm and duodenal ulcer has been briefly discussed.

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32. Eppinger H., and Hess, L.: Vagotomia, New York, Nervous and Mental Disease Publishing Co., 1915.

33. Finney, M. T., and Friedenwald, J.: Am. J. M. Sc. **162**:469, 1921.

34. Morton, C. B.: Hypertonicity and Hypertrophy of Pylorus in Adults, Arch. Surg. **20**:508 (March) 1930.

35. Archer, V. W.: Am. J. Roentgenol. **23**:510, 1930.

THE RELATIVE EFFECT OF CONTRACTION OF THE DIAPHRAGM ON THE BRONCHI OF THE UPPER AND LOWER LOBES*

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The large number of operations on the phrenic nerve performed in recent years has stimulated interest in the relative effect of contraction of the diaphragm on the upper and lower lobes of the lung. Paralysis of the diaphragm by section of the phrenic nerve was first advised for disease of the lower lobe, but more recently it has been advocated for involvement of the upper lobe also. The question as to which lobe under similar conditions is more benefited by paralysis of the diaphragm is still unsettled. Some surgeons report more favorable results on lesions of the lower lobe; others believe that the upper and lower lobes are equally benefited. With that issue in view, these experiments were carried out.

EXPERIMENTAL METHODS

No method has been devised by which the respired air from an individual pulmonary lobe can be measured satisfactorily, but one would expect the changes in the bronchial length to correspond closely with the changes in the volume of respired air. Therefore, it was decided to determine the changes in the bronchi of the upper and lower lobes produced by contraction of the diaphragm.

The method used to demonstrate the bronchi was that described by Francis.[1] Dogs were anesthetized by barbital intravenously and in the later series by amytal intraperitoneally. A bronchoscope was inserted, and a straight tube with a flexible tip was passed through this for insuf-

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1. Francis, Byron F.: The Changes in Shape and Size of the Tracheo-Bronchial Tree Following Stimulation of the Vago-Sympathetic Nerve, Arch. Surg. **19**:1577 (Dec.) 1929.

flation of the lower lobe and a metal tube with a short 60 degree side-arm was used for insufflations of the upper lobe. Bismuth subcarbonate, thoroughly dried, was insufflated through this tube into the bronchi by compressed air. After the first few experiments it was decided to confine the studies to the bronchi of the right lung, because the upper main bronchus was more accessible and superimposed shadows were avoided on the lateral x-ray plates. The right phrenic nerve was exposed and divided, and the distal end was stimulated by a faradic current. Two

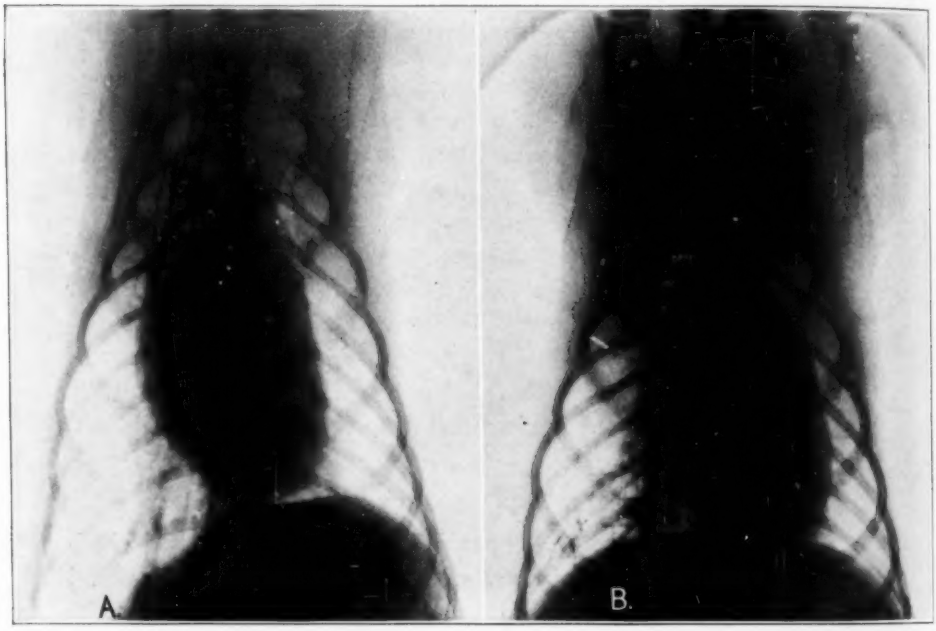

Fig. 1 (dog 17).—Roentgenograms made in the dorsal position. *A* shows marked contraction of the right side of the diaphragm with lengthening of the bronchi; *B*, shortening of the bronchi during expiration.

roentgenograms were made with the dog in the dorsal position, one while the nerve was being stimulated and another at expiration with the nerve divided. Then the dog was turned on the right side (care being taken to have the sternum on the same level with the spine), and two more roentgenograms were made, one while the nerve was being stimulated and another at expiration. All were made at a distance of approximately 6 feet. Points anatomically identical in both the bronchi of the upper and lower lobes were selected in those made in the dorsal position, and the distance between these points measured. The angle of deviation of the

bronchi from the perpendicular was determined in the two lateral plates and used to calculate the length of the bronchi. The following formula was used to compute the actual length:

$$\text{Actual length} = \frac{\text{Length measured on dorsal plate}}{\text{Cosine of angle of deviation in lateral plate}}$$

Twenty-eight experiments were carried out, but only eight were considered satisfactory for measurements. The first experiments were

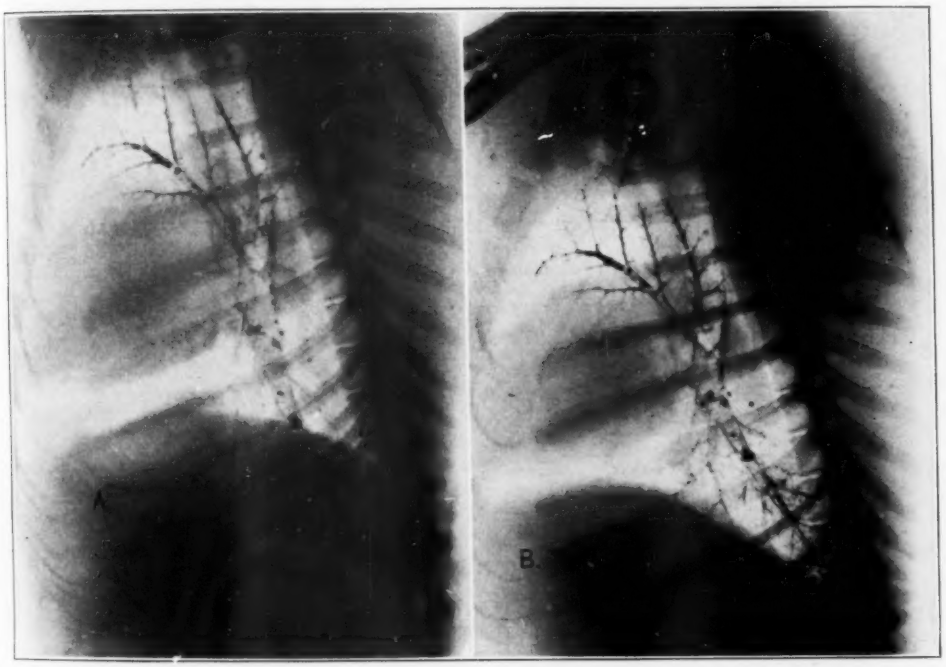

Fig. 2 (dog 17).—Roentgenograms made in the lateral position. *A*, made during contraction of the right side of the diaphragm, shows how the bronchi approach the horizontal when the dog is in the dorsal position. *B*, made during expiration, shows how they deviate from the horizontal when the dog is in the dorsal position.

unsatisfactory because too much bismuth had been insufflated, with the result that the bronchi were occluded, which prevented an expansion of the lung and lengthening of the bronchi. In the later experiments, only a very small amount of bismuth was insufflated, with much better results. Typical plates are shown in figures 1 and 2. Table 1 gives the length of the bronchial shadows and angles of deviation from the perpendicular, and table 2, the calculated length of the bronchi.

TABLE 1.—*Measurement of the Length of the Bronchi in the Dorsal Plates and of the Angle of Deviation in the Lateral Plates*

Dog	Lobe of Lung	Length of Bronchi in the Dorsal Plates, Mm.		Deviation from the Perpendicular in the Lateral Plates, Degrees	
		During Stimulation of Phrenic Nerve	At Expiration	During Stimulation of Phrenic Nerve	At Expiration
		(1)	(2)	(3)	(4)
16	Right upper	40	29	52	52
	Right lower	86	57	14	26
17	Right upper	55	46	0	0
	Right lower	89	66	10	10
18	Right upper	41	31	57	59
	Right lower	68	47	27	33
19	Right upper	55	40	10	15
	Right lower	115	71	15	29
20	Right upper	42	32	50	53
	Right lower	87	54	13	32
21	Right upper	31	24	37	47
	Right lower	56	46	10	17
24	Right upper	44	31	35	45
	Right lower	82	55	15	25
28	Right upper	36	32	24	26
	Right lower	58	51	21	24

TABLE 2.—*Percentage Lengthening of the Bronchi During Stimulation of the Phrenic Nerve*

Dog	Right Upper Lobe	Right Lower Lobe
16	38	39
17	19	34
18	25	33
19	34	46
20	30	41
21	8	16
24	23	40
28	12	13
Average	21	34
Difference		13

REVIEW OF LITERATURE

No experiments bearing directly on this subject could be found in the literature. Walsh,[2] in a clinical and pathologic study, concluded that the activity of the lung was greatest at the apex and least at the base. Sergent[3] was able to demonstrate by x-ray studies that the greatest activity occurred in the anterolateral portion of the lung and the least activity posteriorly and at the apex.

2. Walsh, Joseph: Pulmonary Activity Greatest at the Apex and Least at the Base, Am. Rev. Tuberc. **14**:142, 1926.

3. Sergent, E.: The Motor Independence of Pulmonary Lobes, Semaine d. hôp. de Paris **3**:157, 1927.

COMMENT

Walsh concluded that the pulmonary activity was greatest at the apex and least at the base on the basis: first, that pulmonary tuberculosis develops most frequently in the upper portion of the lung, and even miliary tuberculosis advances more rapidly in the upper lobe; second, that the pulmonary alveoli are larger at the apex than at the base in the normal lung. In emphysematous lungs, the alveoli are greatly dilated at the apex and only slightly dilated at the base.

No logical explanation has yet been offered for the fact that pulmonary tuberculosis develops usually in the upper portion of the lung, but the fact remains that the earliest lesions are not in the extreme apex but in the infraclavicular region. If the question were entirely one of greater activity as stressed by Walsh, one would expect the earliest lesions in the extreme apex. He laid greatest stress on the enlargement of the apical alveoli. This is an anatomic fact, but it would appear that respiration plays a relatively small part in the dilatation of the alveoli, as the intrapulmonary pressure does not reach atmospheric pressure during any phase of normal breathing. Coughing and straining raise the intrapulmonary pressure above atmospheric pressure, so they would be expected to play a large part in the dilatation of the alveoli. During increased intrapulmonary pressure, the lung distends at the point of least outside support, which is at the apex.

The ideas presented in this paper agree much more closely with those of Sergent. While he does not attempt to discuss the question of the part played by the thoracic wall and diaphragm in the activity of the lung, he does believe that the activity of the lung, as the result of movement of the thoracic wall, is less at the apex posteriorly and greater below and in front. It seems logical to suppose that the effect of contraction of the diaphragm acting through an elastic pulmonary tissue would be greatest at the base, and would diminish as the distance from the diaphragm increased.

In this series of experiments the percentage lengthening of the bronchi of the lower lobe was uniformly greater than that of the upper lobe, and the percentage difference varied directly with the degree of contraction of the diaphragm. If the change in bronchial length is taken as an indication of the change in respired air, contraction of the diaphragm produces a slightly greater effect on the lower than on the upper lobe. However, this difference is so slight during normal respiration that it is of no practical importance.

A REVIEW OF UROLOGIC SURGERY

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URETHRA

Tumor.—Schiftan [39] reported 5 cases of papillomatosis of the urethra observed in the last two years in the dermatologic clinic of the Britz Hospital in Berlin. There was one case of multiple papillomatosis of the anterior urethra. In all of the cases there was a history of previous gonorrheal infection.

The papillomas were treated by electric cautery. A proprietary cocaine mixture was used as a local anesthetic. In spite of the care in protecting the urethra at the time of treatment, a beginning stricture was noticed while the patient was still under treatment. The prognosis in these cases is poor because of the possibility of malignant changes.

[ED. NOTE.—Polyps and papillomas of the urethra are not uncommon. They are usually very small and the result of long and tedious urethral infections. They have little clinical significance. In most cases they disappear following treatment for the underlying infection. Both the small and the large tumors respond readily to fulguration or snaring. Those occurring in the posterior urethra of male patients may be pedunculated and occasionally interfere with the closure of the internal sphincter; those occurring near the external orifice are generally flat and sessile. Multiple and extensive growths are occasionally seen. Zuckerkandl reported a case in which a papillomatous growth covered the entire urethra. There is a tendency to rapid and extensive recurrence after removal. Elder and Lewin both reported cases in which the recurring papilloma completely filled the urethra.]

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39. Schiftan, Walter: Papillomatosis der männlichen Harnrörhe, Ztschr. f. Urol. **24**:518, 1930.

Valve Obstruction.—Campbell [40] reported 18 cases of congenital obstruction of the posterior urethral valve, all occurring among children. Urethral valves are the most common congenital infravesical obstruction, and because they are confined to the prostatic canal are limited to male patients. When because of situation or size the valves produce symptoms, the clinical manifestations are those of obstruction; secondary symptoms are those of uremia. Diagnosis is made by cysto-urethroscopy, and the prognosis is directly proportional to the renal function.

Structurally, valves may be present only as low ridges; these do not obstruct. More often valves appear as mucosal folds or redundances and, in retarding a fluid stream, may be cystoscopically observed to balloon into cusp formation. They may also be present as partial or complete diaphragms. Most valves are contiguous with the verumontanum at some point and usually pass from the anterior end of the verumontanum to the lateral urethral walls; in several instances extension from the posterior verumontanum to the outlet of the bladder was observed. Segments of valves of the latter type are likely to be multiple; six or seven folds may extend from the verumontanum posteriorly into the outlet of the bladder. Valves may be unilateral. The valve may be totally independent of the verumontanum, situated either anterior or posterior to this organ. In the presence of valves, the verumontanum is usually anomalous; enlargement and great elongation is the rule. Sometimes the verumontanum extends from the vesical outlet anteriorly for 2 or 3 cm.

The pathologic changes in the urinary tract are those common to all infravesical obstructions. Until prolonged back pressure causes muscular decompensation, the wall of the bladder shows trabeculation, hypertrophy and sometimes inflammation, and may be the site of the diverticulum. Often there is trigonal hypertrophy. With decompensation, the bladder becomes a large, hypotonic bag. Ureteral and pelvic dilatation occur as the disease advances; urinary back pressure, as well as inflammatory changes, destroys the ureterovesical valve, so that vesico-ureteral reflux is demonstrable in most advanced cases. The ureters may become larger than the colon; the renal parenchyma is frequently compressed to a thin shell. Nephritis from compression, with infection, leads to reduction of renal function as the disease progresses.

Urinary frequency is the most common symptom and is usually present from birth. After infection has set in, the child may urinate every twenty to thirty minutes. In many instances overflow incontinence may keep the child continually wet, and the condition will be diagnosed

40. Campbell, M. F.: Obstruction of the Posterior Urethral Valve in Infancy and Childhood, J. A. M. A. **96**:592 (Feb. 21) 1931.

as enuresis. Dysuria is due to the diminished urethral caliber and is often distressing. Chronic distention of the bladder is sometimes manifest by protuberance of the lower part of the abdomen; frequently the mother or the patient has palpated the vesical mass.

Laboratory examination discloses urinary infection in most instances. In advanced cases, the urinalysis often leads to the diagnosis of chronic interstitial nephritis.

Treatment should be removal of the obstruction, but this should not be attempted until the condition of the patient warrants surgical procedures. If the residual urine is more than 3 ounces (90 cc.), gradual decompression and continuous drainage of the bladder should be carried out until functional stability has been established. If the residual urine is less than 90 cc., preliminary drainage for a few days is excellent practice. Several methods of removal of the valve have been advocated. Perineal approach is unsatisfactory and unnecessary. If the urethra is impassable or drainage has been instituted by cystotomy, suprapubic attack may be carried out. Fluid in abundance is the best medicine after operation. If the obstruction has been properly removed, urination will be free.

Trichomonas Infection.—Riba [41] reported several cases of trichomonas urethritis and observed that the presence of the trichomonas is not limited to the female genital tract, but may occur in the male. Urethritis of the male patient may be complicated with prostatovesiculitis. The motile protozoa may be readily demonstrated in fresh wet preparations, and the nonspecific urethral and prostatic secretions should be examined in their natural state.

PENIS

Carcinoma.—Colby and Smith [42] reported a study of 50 cases of carcinoma of the penis to determine the correlation of the degree of malignancy of tumors, as determined by their histologic appearance, and their clinical course. With the histologic appearance as a basis, the tumors were graded as to malignancy into low and high. Twenty-six cases were of low grade and 24 of high grade. Partial amputation was performed in 27 cases, total amputation or emasculation in 16, minor operative procedures or radium in 7, and one or both groins were dissected in 32.

The average age of the patients was 59 years. Definite phimosis had existed in about half the cases, and, as far as could be determined, none of the patients had been circumcised in infancy or early childhood.

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41. Riba, L. W.: Trichomonas Urethritis, J. A. M. A. **96**:2100 (June 20) 1931.

42. Colby, F. H., and Smith, G. G.: Carcinoma of the Penis, J. Urol. **25**:461 (May) 1931.

Thirty-eight (76 per cent) of the 50 patients were traced after operation at varying intervals up to ten years. In comparing the postoperative course of the two groups, it was found that 10.5 per cent of those with tumors of low grade malignancy died of carcinoma within the first two years, and 36.8 per cent of those in which the malignancy was high died of carcinoma within the first year. In the first group a higher proportion of patients were living for a period of years than in the second group.

The advisability of dissection of the groin seemed to be important. Of the entire 14 cases of both groups in which the groins were not dissected, 75 per cent of patients in the first group and 83.3 per cent in the second group lived for varying intervals without evidence of carcinoma. None of the patients of the first group died of the malignant lesion, while one patient (16.6 per cent) of the second group died. In 10 of the 14 cases partial amputation was performed, in 3 circumcision alone, and in 1 case radium alone was applied.

In the 24 cases in which the groin was dissected, 63.6 per cent of patients of the first group and 38.4 per cent of the second group are living for varying intervals free from carcinoma. Eighteen per cent of patients of the first group and 46.1 per cent of the second group died of the disease. In the series of 50 cases the groin was dissected in 32 (64 per cent). In 24 per cent of cases in the first group and in 62 per cent of the second group, malignant nodes were found on microscopic examination, showing a greater tendency for the more malignant type of tumor to involve the lymph nodes. Of the cases in which malignant nodes were found, 50 per cent of patients of the first group and 70 per cent of the second group died of carcinoma. In 11 of the 50 cases, the groin was dissected although nodes had not been palpable. In 4 (36.3 per cent) of these cases, malignant nodes were found on microscopic examination.

It is Colby and Smith's belief that dissection of the groin should be performed as a routine part of the operative treatment for carcinoma of the penis except in cases in which the disease has existed only for a short time. Conservative surgical measures, such as excision or irradiation, may often be employed, with a reasonable expectation of cure.

Barney,[43] in a follow-up study of 90 cases of carcinoma of the penis, found that phimosis of long duration had occurred in 85 per cent. As a corollary they found that if circumcision had not been performed in infancy or childhood, carcinoma did not develop. Most deaths from carcinoma of the penis are due to internal metastasis which may occur without involvement of the inguinal nodes, or even if they are excised. The deep lymphatic glands of the penis are as efficient in

43. Barney, J. D.: Discussion, J. Urol. **25**:482 (May) 1931.

carrying metastatic cells as are the more superficial ones which pass to the groin. In giving a prognosis in such cases, this fact should be taken into consideration.

TESTIS AND EPIDIDYMIS

Tumor.—Von Illyés [44] reported a case of hypernephroma of the testis. Many years ago an operation had been performed on the left undescended testis. The testis had been enlarged for two years, and when examined it measured about 10 cm. in diameter and was irregular. The epididymis was also enlarged because of the presence of hydrocele. Cystoscopic examination revealed that the urine from the left kidney was thick and purulent. The right side was normal. The left kidney was removed, and the ureter was found to be compressed by tumor. Later, the enlarged testis was removed. Microscopic examination of both specimens revealed hypernephroma. Although the metastatic growth in this case was small, owing to its position it compressed the ureter and caused infected hydronephrosis.

Undescended Testis.—Goetsch [45] reviewed 32 cases of undescended testis and summarized his observations as follows: There is no evidence that an undescended testis properly placed in the scrotum has any greater malignant potentialities than the testis that has always been in normal position. Undescended testis is practically always accompanied by congenital hernia. Sacrifice of the undescended testis is not warranted, since most of them, including those in the abdomen, can be satisfactorily placed in the scrotum by the Bevan operation. Undescended testes lose the power of spermatogenesis but continue to elaborate internal secretion. The scrotal position is necessary for complete anatomic and physiologic development of the testis. Even the atrophic testis with questionable spermatogenesis should be conserved for the influence it may exert in the development of the secondary sex characteristics. Spermatic circulation should not be eliminated if mobilization is at all possible without division. Loss of the spermatic circulation invariably leads to marked atrophy and sometimes to complete atrophy.

UROGRAPHY

Braasch [46] reviewed a series of 40 cases of proved renal lithiasis, in which intravenous urography was done. This procedure was of particular value in identification of shadows, determination of the intra-

44. von Illyés, Géza: Hypernephrom des Hodens, mit einem zweiten Ureter-Kompression verursachenden Herd, Ztschr. f. urol. Chir. **30**:70, 1930; abstr. in Am. J. Cancer **15**:506 (Jan.) 1931.

45. Goetsch, Arthur: Undescended Testis: Review of Thirty-Two Operative Cases, Am. J. Surg. **12**:63 (April) 1931.

46. Braasch, W. F.: The Value of Uroselectan in Renal Lithiasis, J. Urol. **25**: 265 (March) 1931.

renal situation of shadows, ascertaining the differential renal function, demonstration of coincident disease or anomaly in the affected kidney and determination of the functional capacity and disease or abnormality in the other kidney.

The only advantage of intravenous urography over the retrograde method in the identification of renal shadows is that it can be used as a routine in many cases in which cystoscopic examination might not be advisable. Shadows that are seemingly intrarenal or extrarenal on interpretation of the original film often prove to be the opposite in the intravenous urogram. In doubtful cases, both methods of pyelography should be employed. Small shadows in the renal pelvis, which do not cause stasis, occasionally may remain unidentified by intravenous urography because of lack of detail in the minor calices. By intravenous urography, exposures can be made with the patient in different positions, and the kidney may be displaced so as to determine differences in the relative position of the pelvis and of the shadow in question. In this type of procedure the density of the pelvic shadow is usually less than that of the calculus, and as a result the outline of the calculus commonly can be seen through that of the pelvis. In some cases the density is not then visible. It has particular value in cases of stones situated in the ends of the calices, since it gives a better idea than retrograde urography as to their exact position and the feasibility of their removal.

The visual estimate of renal function made possible by intravenous urography is often more accurate and satisfactory than the usual tests of renal function in the presence of renal calculus. Both the test with phenolsulphonphthalein and that with indigo carmine are misleading in determining the functional capacity of a kidney which contains a calculus. Iopax gives evidence which leads to the belief that bilateral involvement of the kidney occurs more commonly than previously was supposed.

Retrograde urography, with stone in the ureter, frequently is followed by serious febrile reactions, particularly when there is pyelectasis and when renal drainage is obstructed. Intravenous urography obviates this and often furnishes diagnostic data not possible with retrograde urography.

Bugbee and Murphy [47] stated that, in any new discovery, the tendency has been to overestimate the possibilities of its usefulness. They believe that intravenous urography is primarily a method of corroboration, to be employed as a supplement to the present methods of urologic diagnosis, except in the limited number of cases in which cystoscopic manipulation is impossible. In such cases it gives valuable

47. Bugbee, H. G., and Murphy, A. J.: The Value and Limitations of Uroselectan as an Aid in Urological Diagnosis, J. Urol. **25**:275 (March) 1931.

data otherwise unavailable, but when unsupported by cystoscopic information the interpretations must be made with extreme care and conservatism.

Lowsley [48] stated that in a series of 45 cases intravenous pyelography with iopax was found a helpful adjunct, particularly in tuberculosis of the urinary tract. When the serious general condition of certain patients with tuberculosis precludes cystoscopic examination, intravenous pyelography frequently furnishes sufficient information so that further investigation is unnecessary.

Herbst [49] stated that iopax may be used in practically all cases in which the cystoscopic pyelogram is used, and also in some cases in which the retrograde method is inadvisable or impossible. Tumor of the kidney, polycystic kidney and early renal tuberculosis cannot be studied as satisfactorily by the use of iopax as by cystoscopic examination. Interpretation of intravenous films is difficult if there is gas in the bowel and the torso is thick. Iopax will be particularly valuable in the diagnosis of urologic disorders of children. It will often be used in preference to cystoscopic examination, thus avoiding a general anesthetic and its attendant difficulties.

Von Lichtenberg [50] formulated the indications and limitations of intravenous urography by clinically interpreting the results in more than 700 cases. One hundred cubic centimeters of a 40 per cent solution of iopax was used, the first picture taken a quarter of an hour, the second three-quarters of an hour and the third an hour and a quarter after intravenous injections.

By intravenous urography with iopax, visualization of the urinary tract and the relationship between various parts of the urinary tract may be obtained. Important data concerning renal function may also be obtained by roentgenologic means and by qualitative and quantitative chemical data. It also enables interpretation of the dynamics of the urinary tract by observing the expulsion of iopax. A good picture is expected only when renal function is satisfactory, because the intensity of the roentgen ray is dependent mostly on the function of the kidney.

Intravenous urography can be used in cases in which cystoscopic examination fails or is unusually difficult, if catheterization of the ureters or instrumental pyelography cannot be done, or if this method does not afford definite information. It can also be used in cases in which instrumental pyelography should not be done, because of the

48. Lowsley, O. S.: Uroselectan in Urinary Tuberculosis, J. Urol. **25**:293 (March) 1931.

49. Herbst, R. H.: Comparative Value of Uroselectan to Cystoscopic Pyelography, J. Urol. **25**:287 (March) 1931.

50. von Lichtenberg, Alexander: The Principles of Intravenous Urography, J. Urol. **25**:249 (March) 1931.

possible injury that might result. It affords full information concerning the urinary tract in cases of urethral strictures, severe disease of the bladder, bleeding, ruptured kidneys, fistulas, in cases of transplanted ureters and in the examination of young children.

Beer [51] stated that fluoroscopy of the exposed kidney in the search for stones was advanced by Braasch and proved of great aid in localizing fragments of stone that might be removed at the time of operation. Experience demonstrated that small fragments escaped the attention of the fluoroscopist, and frequently were recovered by palpation and irrigation, after the kidney was thought to be empty, or were seen in a few weeks in control pictures during convalescence. Quinby then suggested that a small film be placed against the exposed wall and well delivered kidney and a roentgenogram made.

Beer expressed the belief that every fragment of stone not recovered by roentgenographic control on the table, or by irrigation or drainage through a nephrostomy tube, is a potential source of danger to the patient and often counteracts attempts at a complete and definite cure. For the last five years he had been using roentgenograms as controls in operations for stone in the kidney. The method of making films of the kidney by means of the improved casette and intensifying screen is used regularly in all complicated cases and in all cases of multiple calculi. Roentgenographic control has repeatedly shown stones or fragments in the cavities of the kidney or parenchyma, even after careful search and prolonged, forceful irrigation of the pelvis and calices. In cases in which fragments are left behind, it is Beer's custom to drain by nephrostomy and to irrigate in the hope that unrecovered fragments may be discharged spontaneously or be washed out.

In more than 50 complicated cases of stone, roentgenographic control of the exposed kidney was used. Small fragments and even sizable stones were overlooked in a relatively large percentage of cases, after complete removal had ostensibly been carried out and after thorough irrigation of the pelvis of the kidney and calices. In the majority of these checked cases the fragments or stones were removed after localization by the roentgenogram.

[Ed. Note.—The prevention of recurrence of urolithiasis demands thorough operative removal of all stones or fragments of stones, the elimination of infection and the establishment of adequate drainage of the urinary tract. The first consideration is of paramount importance, as many so-called recurrences have been the signs of incomplete operative removal of calculi.

51. Beer, Edwin: Roentgenological Control of Exposed Kidneys in Operations for Nephrolithiasis, with the use of Special Intensifying Casette, J. Urol. **25**:159 (Feb.) 1931.

The use of the fluoroscope at the operating table, as developed by Braasch and Carman, was of the utmost value in localizing stones or fragments which otherwise would have been overlooked. The casettes described by Beer and Benjamin perhaps give a better opportunity to pick up fragments of stone, and thus represent a further advance in the use of the roentgen ray in the surgical removal of renal calculus.]

Benjamin [52] stated that in about 25 to 50 per cent of the cases of renal lithiasis checked by the control roentgenograms, stones had been incompletely removed, although the operations were performed by competent urologic surgeons. Stones 1.5 cm. in diameter had been overlooked. Interpretation of control roentgenograms of the kidney is not without its inherent difficulties. The presence of blood clots, coagulated tissue fluids and overlapping detached soft tissues, may be confusing. It is essential to read the film while it is wet.

A special small casette measuring 3¾ by 4¾ inches (8 by 10 cm.) has recently been designed by Jaches; this has an aluminum cover and contains a double intensifying screen. It reduces the exposure time to a tenth of that of the ordinary film and insures sharp, clear pictures, even with the patient under light anesthesia. The casette is firm and not subject to buckling, thus eliminating artefacts which occurred with the use of the ordinary film. It is readily kept clean and easily and rapidly reloaded. Exposure is made from in front of the patient. The time is about half a second or less, at a distance of about 30 to 48 cm. Guide needles are inserted into the exposed kidney by the surgeon. The loaded casette is dropped into a sterile rubber bag the inside of which has been carefully wiped dry, and the casette is then tucked behind the kidney, care being taken to cover it entirely; if this cannot be done, the portion of the kidney under suspicion is covered. Either side of the casette may be used against the kidney.

NERVE CONTROL OF KIDNEY, URETER AND BLADDER

Harris and Harris [53] stated that in a large number of cases in which there is renal pain without demonstrable abnormalities except positive response to a test for pain, delayed emptying time of the pelvis and perhaps slight clubbing of the calices which increases renal sympatheticotonus are the cause of the symptoms and that renal denervation will give relief.

Since the introduction of pyeloscopy these authors have been able to demonstrate motor disturbances of the renal calices, pelvis and ureters

52. Benjamin, E. W.: Notes on the Technique of X-Ray Control in the Operating Room, J. Urol. **25**:165 (Feb.) 1931.

53. Harris, S. H., and Harris, R. G. S.: Renal Sympathetico-Tonus, Renal Pain and Renal Sympathectomy, Brit. J. Urol. **2**:367 (Dec.) 1930.

and have defined the urographic evidence of renal sympatheticotonus and the indications for sympathectomy as: (1) irregular and incomplete contractions of the calices and the renal pelvis; the condition is a fibrillation with interference with the normal peristaltic rhythm; (2) marked slowing with irregularity and increased power of the contractions, associated generally with dilatation of the renal pelvis and clubbing of the calices; delayed emptying time is a feature also, and (3) dilatation and immobilty of a single calix with delayed emptying time, and localized sympatheticotonus.

With these urographic observations, a positive pain reproduction test, evidence of generalized sympatheticotonus, with negative urinary findings, and the proved absence of any organic lesion, renal denervation may be undertaken with the assurance that there will be complete and permanent relief from pain. The operation consists in denudation of the vessels of the renal pedicle, working from within outward toward the kidney. The pelvis and first inch of the ureters are also freed of connective tissue.

Farrell [54] studied the vesicorenal reflexes and the possibility of a renorenal reflex. Twenty-five dogs were used in the experiments, which were performed under morphine and ether anesthesia because it was fairly uniform and exerted little influence on the flow of urine.

It was observed that both distention of the bladder and stimulation of the pelvic nerve produced a change in the renal volume and inhibition of the urinary flow which might be partial or complete. No change in urinary flow resulted from stimulation of the hypogastric nerve, nor, when the splanchnic nerve was sectioned, from the distention of the bladder or stimulation of the pelvic nerve. Distention of the renal pelvis on one side caused inhibition of flow of urine and vasoconstriction of the vessels of the opposite kidney which was manifested by reduction in volume of the kidney. This reduction in volume can be magnified if a diuretic such as dextrose is injected immediately before the distention of the renal pelvis. During urination, urine did not flow from the ureters, apparently a protective mechanism to prevent back pressure on the kidney.

Farrell concluded that many of the impulses arising from the afferent nerves to the bladder traverse the pelvic nerve. Most of the efferent fibers in the splanchnic nerve to the kidney are probably vasomotor. A reflex relation exists between the bladder and kidneys. When the bladder is distended, the flow of urine is diminished, probably a protective mechanism to prevent pressure within the renal pelvis. In clinical cases of retention of urine, when the bladder is chronically distended, this reflex apparently is destroyed, since in many such cases

54. Farrell, J. I.: A Study of Vesicorenal Reflexes and of the Possibility of a Renorenal Reflex, J. Urol. **25**:487 (May) 1931.

hydro-ureter and hydronephrosis develop. Clinically, reflex inhibition of secretion of urine has beeen observed following operations on the kidney and others organs, and experimentally, distention of one renal pelvis produces pain, decrease in the blood pressure and inhibition of the flow of urine on the opposite side. Although it is probable that this inhibition is the result of vasomotor changes within the kidney, it is possible to influence the urinary secretion of one kidney by distending the pelvis of the opposite kidney. If this interpretation is correct, it would serve to substantiate the existence of a renorenal reflex.

Wharton and Hughson [55] reported two cases of persistent and severe ureteral pain. The patients were definitely relieved at first by ureteral dilatation. When this failed to give relief from pain, ureteral denervation accomplished complete cure in both cases. One patient has been well for almost six years, the other for three and a half years.

The interpretation of the condition of the ureter was difficult. In no instance was there any obstruction to the passage of a number 8 renal catheter. In all cases wax bulbs approximately 4 mm. in size hung on being withdrawn. In only one of the three ureters was there dilatation of hydronephrosis. The urine was sterile and clear. The condition did not indicate any intrinsic diminution of the caliber of the ureter and excluded organic ureteral obstruction and stricture, but seemed to signify a persistent state of spasticity. The fact that denervation of the ureter cured the condition entirely apparently substantiates this. Denervation in these cases was not followed by evidence of ureteral or renal dysfunction. The marked decrease in the sensitiveness of the ureter after denervation was shown by postoperative urologic study.

[Ed. Note.—Again we meet the problem of pain referred to the urinary tract with little if any pathologic change demonstrable grossly. In this country urologists, after Hunner, have attempted to ascribe the underlying causes for the most part to ureteral stricture, ureteral kinks and similar conditions. Ureteral dilatation as a means of relief, although never uniformly accepted or popular, has held and still holds a prominent place in treatment.

During the last five years a newer concept of neuromotor dysfunction as a cause of painful hydronephrosis, of peristent renal and ureteral spasms and of so-called nephritis dolorosa, has become prominent. Denervation procedures such as those of Legueu and Papin have been reported with variable results. The reports of Harris and Harris, and Wharton and Hughson reflect the influence of this application of neuroexeresis to urologic conditions.

55. Wharton, L. R., and Hughson, Walter: Denervation of the Ureter, J. Urol. **25**:145 (Feb.) 1931.

Much controversial opinion exists, especially among the more conservative observers, with regard to the significance of minor changes from the normal in interpreting urograms. Thus the slight clubbing of single calices, hyperperistalsis of the ureter and pelvis, slight pyelectasis and ureteral dilatations are frequently considered within the range of normal, especially in the absence of stone or infection.

The fact remains that frequently persistent disabling pain referable to the kidney and ureter is observed, and ureteral dilatation often gives relief for a time at least. However, some conditions are resistant, and in these the principles of neurosurgical denervation may be applied with some prospect of relief as Wharton and Hughson have outlined.]

Papin [56] stated that all denervation of the ureter follows the blood supply. Following each vessel there is a plexus of nerves that comes to a different level in the ureter. As soon as they arrive at the ureter, the normal plexus communicates above and below. Both the arteries and the nerves anastomose and form this plexus. In order to denervate the ureter, it would be necessary to remove the nerve from each of the small arteries.

Nerve Control.—Gurdjian [57] stated that retention is the first manifestation of urinary dysfunction in traumatic myelitis. Severe injury to the cord is not always associated with urinary dysfunction. The evolution of urinary disturbances in traumatic myelitis is usually: (1) retention, or retention with overflow; (2) a period of retention with active incontinence or retention alternating with voluntary urination; (3) active incontinence or complete recovery of function, and (4) in cases with active incontinence with urinary infection, complete incontinence or constant dribbling may develop. The period of retention varied on the average from three to five weeks. Extreme distention of the bladder favors return of function or the production of automatic bladder. In a case of infected bladder with distention, the patient should be placed on continuous drainage or catheterized at frequent and regular intervals. Urinary antiseptics and mild irrigation of the bladder are also indicated.

Learmonth [58] considered the principal sources of nerves to the bladder and posterior urethra. These are mainly the presacral nerve, the pelvic nerve and the pudic nerve. The presacral nerve contains fibers that are: (1) inhibitory to the expulsive muscles of the bladder; (2) motor to the muscle around the ureterovesical orifices; (3) motor to the muscle of the trigone; (4) motor to the internal sphincter;

56. Papin, E.: Discussion, J. Urol. **25**:181 (Feb.) 1931.

57. Gurdjian, E. S.: Urinary Tract Manifestations in Traumatic Myelitis, Am. J. Surg. **12**:112 (April) 1931.

58. Learmonth, J. R.: The Nerves of the Urinary Bladder in the Human Being, Proc. Staff Meet., Mayo Clinic **6**:182 (March 25) 1931.

(5) motor to the smooth muscle of the prostate gland; (6) motor to the smooth muscle of the seminal vesicles and ejaculatory ducts; (7) afferent, conveying impressions of distention of the bladder; (8) afferent, conveying impressions of pain on spasmodic contraction of the bladder, and (9) vasoconstrictor to the vessels of the bladder. The pelvic nerves contain fibers that are: (1) motor to the expulsive muscles of the bladder; (2) inhibitory to the internal sphincter; (3) afferent, for the micturition reflex, and (4) afferent, for tactile and painful impulses from the bladder, and, at least in part, from the posterior urethra. The pudic nerve is said to supply some sensory fibers to the posterior urethra; it provides motor nerves for the external sphincter. Apparently integrity of the pelvic nerves alone is essential for the act of micturition.

[ED. NOTE.—Section of the nerve, stimulated by the work of Hunter and Royle, has been done for a variety of neurospastic conditions during the last decade. Learmonth's anatomic study following up the work of Laux and Latarget with regard to the innervation of the bladder is timely and promising. By sectioning the presacral nerve in certain types of paralysis of the bladder, the function of micturition of the pelvic nerves (these being intact) has been reestablished in a few instances. Although this work is still in the developmental stage, the initial results are encouraging and seem to make the procedure worthy of further clinical trial in the hands of the trained, conservative neurosurgeon.]

SURGERY OF THE GENITO-URINARY SYSTEM

Walters [59] reported that in 1930 at the Mayo Clinic, 1,247 operations were performed on the urinary tract. Three hundred eleven operations were performed on the kidney, with 10 deaths (3.2 per cent). Nephrectomy was done in 165 cases, 7 deaths occurring (4.2 per cent).

There were 10 cases of hydronephrosis in which plastic operations were performed on the renal pelvis. Eight of these operations consisted of resection of the renal pelvis or plastic operation on the obstructed ureteropelvic juncture.

Of 137 operations for nephrolithiasis, pelviolithotomy or nephrolithotomy with preservation of the kidney was performed in 95 cases, and nephrectomy was necessary in only 42. These 42 cases were mainly instances in which the renal parenchyma was largely destroyed or badly infected. Two deaths occurred following operations for nephrolithiasis, both the result of pyelonephritis. Seventy-seven patients were treated for ureterolithiasis. Ureterolithotomy was performed on 50 of the 77 patients, with 2 deaths, 1 of which was due to pulmonary

59. Walters, Waltman: Report of Urologic Surgery (Exclusive of Gynecologic Surgery) for 1930, Proc. Staff Meet., Mayo Clinic **6**:98 (Feb. 18) 1931.

embolism. In the remaining 27 cases the stone was removed by manipulation through the cystoscope by means of ureteral catheters.

Eight patients were operated on for exstrophy of the bladder or for complete epispadias and absence of the urinary sphincters, without deaths. In 7 of these cases both ureters were transplanted into the rectosigmoid, and the bladder was removed. It is noted that in 74 cases of exstrophy of the bladder, the ureters have been transplanted to the rectosigmoid, and the exstrophied bladder has been removed at the Mayo Clinic in the last seventeen years. In this series, 3 patients died from operation (4.2 per cent). In a recent study of these cases, it was found that approximately 81 per cent of patients have had good results from operation, and 14 per cent have had fair results.

In a case of extensive malignant lesion of the bladder in which segmental resection could not be performed, the ureters were transplanted into the sigmoid, and total cystectomy was successfully performed. The prostate gland was removed at the same time with total cystectomy. In one other case of contracted bladder, the result of healed lesions of tuberculosis, and in which one kidney had been removed, the patient recovered following transplantation of the ureter of the remaining kidney into the rectosigmoid.

There were 292 operations on the prostate gland, with a mortality rate of 6.5 per cent. Failure to recover was due to pyelonephritis in 9 cases, bronchopneumonia in 4 and embolic pneumonia in 3, whereas postoperative hemorrhage, cardiac failure and pulmonary embolism each was the cause of 1 death. In this group of 292 cases prostatectomy was performed for carcinoma of the prostate gland in 11. In 59 cases in which the prostatic obstruction was confined to a median bar or contracted vesical neck, the obstruction was relieved by a transurethral punch operation. Prostatectomy was done for fibroadenomatous hypertrophy in 222 cases. Suprapubic cystostomy was done in 230 cases; in 163 it was preliminary to prostatectomy. In 37 cases cystostomy was done to relieve prostatic obstruction, the result of inoperable carcinoma of the prostate gland. In the remainder of the 230 cases cystostomy was done secondarily for conditions such as vesical and prostatic calculi, cord bladder, periurethral abscesses and fistulas.

Sixty-three operations were performed on 52 patients with carcinoma of the bladder. In 18 of these cases the lesion was removed by segmental resection of the bladder. In 20 cases, after suprapubic exploration of the bladder, the lesion was removed by cautery or electrocoagulation, with insertion of radium at the same time in 7 of these. In 4 cases, cystotomy with insertion of radium was carried out alone. In 1 case already mentioned, successful cystectomy was performed after ureterosigmoidal transplantation. There were 65 cases of vesical tumor in which, because of the size and nature of the tumors, the treatment

was electrocoagulation through the cystoscope. This necessitated a total of 115 treatments. Diverticulectomy was performed in 22 cases with 1 death.

Braasch [60] stated that the field of cystoscopic manipulation and operation has been considerably developed. Fifty-nine punch operations were done for prostatic disorders with only 1 death. The operations were performed with a direct vision punch instrument, followed by the application of cautery to bleeding vessels to control the hematuria. Obstructing portions of the prostate gland have been removed by means of the punch operation more generally in recent years. Approximately 25 per cent of the patients with prostatic obstruction observed at the Mayo Clinic are treated by this method. The operation is usually employed only if the obstruction is confined to the median lobe of the gland and to contraction of the vesical neck.

Twenty-seven cases of stone in the ureter were reported, in which the stone was removed by cystoscopic manipulation. This does not include a number of cases in which small calculi were passed some time after ureteral catheterization. By various manipulative measures successful removal of stones from the lower part of the ureter has been done in a high proportion of patients observed in the clinic. Many of the stones removed have been of considerable size. Surgical treatment for small stones in the ureterovesical region is seldom necessary. When the stone is situated above the lower third of the ureter it is usually inadvisable to attempt removal by manipulation; it is better to remove it by surgical operation.

A considerable number of tumors of the bladder were treated by cystoscopic or transurethral methods. The selection of tumors amenable to such treatment is largely dependent on biopsy of specimens removed through the cystoscope. Approximately 25 per cent of tumors of the bladder observed were suitable to cystoscopic manipulation.

TUMORS OF THE GENITO-URINARY TRACT

Dean [61] considered the early symptoms and diagnosis of carcinoma of the genito-urinary tract. Adenocarcinoma or hypernephroma, which is the most common malignant tumor of the kidney, is rarely discovered early. Hematuria is the initial symptom in about 85 per cent of the cases, and may or may not be accompanied by pain. Other symptoms include pain in the region of the kidney, tumor, loss of weight and strength and discomfort due to metastasis. Pyelography aids greatly in the diagnosis, since it shows filling defects in most cases as the growth

60. Braasch, W. F.: Discussion, Proc. Staff Meet., Mayo Clinic **6**:100 (Feb. 18) 1931.

61. Dean, A. L.: Early Symptoms and Diagnosis of Cancer of the Genito-Urinary Organs, Am. J. Surg. **8**:988 (May) 1930.

invades the pelvis. Metastasis occurs most frequently in the lungs, the long bones, especially of the lower extremities, and the bony pelvis.

The usual symptoms of carcinoma of the bladder are hematuria, urinary frequency and dysuria. Cystoscopic examination gives definite and detailed information concerning the condition. Papilloma, papillary carcinoma and flat carcinoma present rather characteristic pictures. Biopsy should be done to determine the type and degree of malignancy, and cystoscopic examination should be supplemented by cystography.

Carcinoma of the prostate gland is not rare and should be considered in the examination of all men of middle age who have urinary symptoms. The onset is insidious, the first symptoms usually being those of obstruction of the bladder. Frequency, difficulty in urination and dysuria are common. Pain low in the back or in the penis, perineum or rectum is usually due to a large congested tumor. Involvement of or pressure on the nerves of the pelvis may cause radiating pains along the thighs. Diagnosis is commonly made by rectal palpation. The prostate gland is usually large, nodular, indurated and fixed. Roentgenograms should be taken of the lumbar portion of the spine, pelvis and femurs in search of metastasis.

Teratoid tumors of the testis usually occur in men aged less than 40 years. The first symptom is a painless swelling of the testes. Palpation discloses a testicular tumor, and examination with transmitted light reveals its solid nature. At the upper limit of the swelling there is usually well defined demarcation. Teratoid tumors are likely to be confused with gumma and tuberculosis. The former usually can be distinguished by a positive Wassermann reaction, and the latter by involvement of the epididymis, prostate gland and seminal vesicles. Abdominal metastatic nodules are deeply situated, rounded, solid and immovable. Metastasis should also be sought in the lungs and mediastinum. If other diagnostic measures are inconclusive, the tumor may be subjected to an erythema dose of high-voltage roentgen rays directed toward the center of the mass. Unless the tumor is composed of radioresistant adult tissues, rapid regression in size will establish the diagnosis.

The two types of carcinoma of the penis, papillary and flat, originate almost invariably beneath a tight, redundant prepuce or one seldom retracted and cleaned. A foul discharge is present in both types. In a series of 75 cases, the first symptom in 73 per cent was a small sore on the penis. In 9 per cent of the cases increased irritation was followed by the appearance of a small sore; in 5 per cent paraphimosis was present, and in 5 per cent warts beneath a tight prepuce were first noticed. Occasionally the first sign of the disease is a hard nodule in the distal third of the penis. When retraction of the prepuce is impossible, a dorsal slit or lateral incision will be required for examination.

The final diagnosis must be made by histologic examination. Inguinal metastatic nodules may be distinguished from purely inflammatory nodules by greater induration and, in the later stages, by immobility.

Astraldi [62] reported on the present status of treatment of tumors of the genito-urinary tract in some of the urologic clinics of Paris. In the service of Legueu, nephrectomy for carcinoma of the kidney is performed without resection of fat; enlarged lymph nodes are excised if found. Roentgen treatment is not employed, and radium treatment is considered impracticable. Ureteral papillomatosis is treated by nephrectomy and total resection of the ureter. In cases of malignant growths of the bladder total cystectomy is performed in two stages. The first stage is bilateral ureterostomy, and the second stage is incision of the bladder two months later. In the interval between operations deep roentgen treatment is employed if the general condition of the patient permits. The mortality is 50 per cent due to the poor condition of the patients rather than to shock. Partial cystectomy is performed if tumors are in the dome of the bladder. Electrocoagulation after cystotomy is a simple and safe procedure; the tumors always recur. The application of radium after cystotomy is of no value. Deep roentgen treatment gives relief from pain, urinary frequency and hematuria; unless the patient is resistant to irradiations, profound anemia will result. Mesothorium is employed in cases beyond surgical aid. Because of the results obtained, Legueu recommends mesothorium in every case of neoplasm of the bladder, irrespective of what has been used or is to be used.

In carcinoma of the prostate gland, Legueu does not resort to operation, roentgen rays or radium. Implantation of radium needles is employed in the treatment for penile carcinoma. Partial or total amputation has been abandoned. Lymph nodes are not treated by roentgen rays, but are resected if enlarged.

Chevassu performs nephrectomy for carcinoma of the kidney only if the tumor is small and if the renal pedicle is not invaded. In his series of 22 cases of nephrectomy for renal carcinoma 18 patients are still living about twelve years after operation. In cases of carcinoma of the prostate gland he uses radium.

Papin treats carcinoma of the kidney by nephrectomy with total resection of the perirenal fat and lymph nodes of the hilus. A cure or at least prolongation of life is obtained in 25 per cent of cases. In carcinoma of the renal pelvis and ureters, the kidney, ureter, ureteral meatus and the corresponding half of the trigonum are removed. Metastasis is infrequent, and the results obtained are good. Perineal

62. Astraldi, Alejandro: Recuerdos Cientificos de Viaje, Rev. de especialid. **5**: 742, 1930; abstr. in Am. J. Cancer **15**:489 (Jan.) 1931.

prostatectomy is done in cases of encapsulated carcinoma of the prostate gland. Tumors that infiltrate beyond the capsule are treated by radium or roentgen rays.

ANURESIS

Eisendrath [63] reported 9 cases of anuresis, and stated that there are three types: secretory, obstructive and transitional.

The secretory type includes all cases in which there is a cessation of secretion as the result of disturbance either next to the kidney or within its parenchyma. There are several classifications in this group. Under disturbances of circulation proximal to the kidney itself may be included vascular spasm of the main renal vessels, probably as the result of stimulation of the splanchnic nerves; anuria as a symptom of hysteria; reflex inhibition of secretion as a result of peripheral irritation; embolism or thrombosis of the main renal vessels of both sides or of one side with reflex irritation of the opposite kidney; marked decrease in blood pressure as often seen in shock, and dehydration due to loss of large quantities of fluid. Under disturbances affecting the renal parenchyma may be placed anuresis complicating the various types of nephritis and nephrosis.

The obstructive type includes unilateral block by calculus, stricture, injury or neoplasm, with the opposite kidney normal. Anuresis in such cases is explained by reflex inhibition of the secretory activity of the opposite organ, a combination of obstructive and secretory anuresis. Another variety of the obstructive type is unilateral block by calculus, stricture, injury or neoplasm with the complete loss of function or absence of the opposite kidney. There is also bilateral block by calculus and stricture.

Among the transitional group are cases following transfusion, burns, infection with gas bacillus, poisoning by potassium chlorate and blackwater fever from malaria. The obstructive factor is in the form of blocking innumerable renal tubules by hemoglobin crystals and a resultant interference with the secretory activity of the renal parenchyma.

In the treatment for anuresis the type should be ascertained as soon as possible. The prognosis is not usually as favorable in the secretory type. The methods of treatment which may be employed are: 1. Administration of large quantities of fluid by proctoclysis, hypodermoclysis, intravenous administration and by the duodenal tube. 2. Nerve blocking, a comparatively recent method, depending on the ability to block the nerves that inhibit renal secretion. 3. Decapsulation. Several cases in which treatment was successful have been reported. Decapsulation for nephrosis caused by corrosive mercuric chloride has only been followed by one recovery in 23 cases reported.

63. Eisendrath, D. N.: Anuria, J. Urol. **25**:421 (April) 1931.

4. Ureteral catheterization. This offers the best outlook in cases of obstructive anuresis and should be given a trial for forty-eight hours but not longer. 5. Operative procedures. These depend somewhat on the experience of the individual operator and are employed in cases in which ureteral catheterizations, splanchnic block and other methods have failed; some surgeons prefer nephrostomy, pyelostomy or ureterostomy, respectively, with removal of the calculus at the same time.

CARCINOMA OF THE SINUS TRACT

Watson[64] stated that continued irritation of urine discharging through sinus tracts from the kidney, ureter, bladder or urethra tends to stimulate hyperplasia, particularly at the epithelial border, and to a lesser extent along the tract itself.

Two cases are reported of primary carcinoma of a suprapubic sinus, each occurring many years after a stricture of the urethra for which suprapubic cystotomy had been performed. One case was of traumatic origin, and the other of gonorrheal. In each case secondary infection had been present for several years. In one case excision, radium and deep roentgen rays were used, but the patient died of generalized carcinoma in three months. In the other case, in which radium implantation and deep roentgen rays were used, the patient lived two years and died of uremia following an operation for hernia. There was no clinical or palpatory evidence of carcinoma.

PYELOVENOUS BACKFLOW

Fuchs[65] found that in acute stasis and increased pressure of the renal pelvis of a rabbit, there is no back pressure into the tubules, but the urine is forced interstitially into the venous system. With the occurrence of acute stasis and increased renal pressure, this interstitial infiltration soon decreases and finally becomes less than the normal renal pressure. If the acute process becomes chronic, there is a corresponding change in the renal parenchyma. In this process the backflow changes from the venous system to the tubular. These observations are correlated to the problem of formation of early hydronephrosis in which there is a decrease in intrarenal pressure. Thus the preliminary conditions for the development of hydronephrosis are formed. Kidneys, such as those of dogs, which lack these phenomena and in which the lower pressure causes backflow into the tubules, become atrophied.

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64. Watson, E. M.: Sinus Tract Carcinoma, J. Urol. **25**:469 (May) 1931.

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